This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

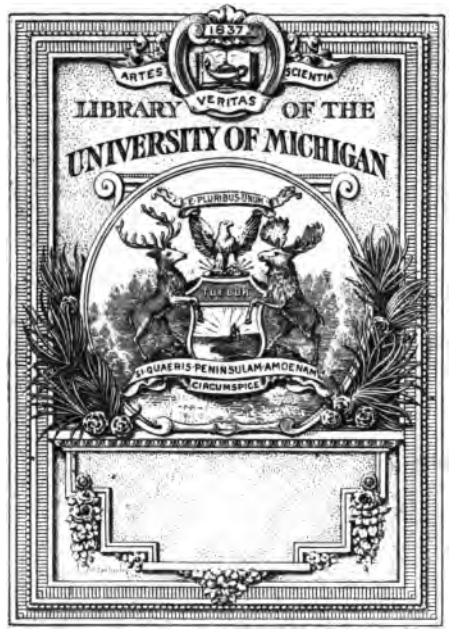
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

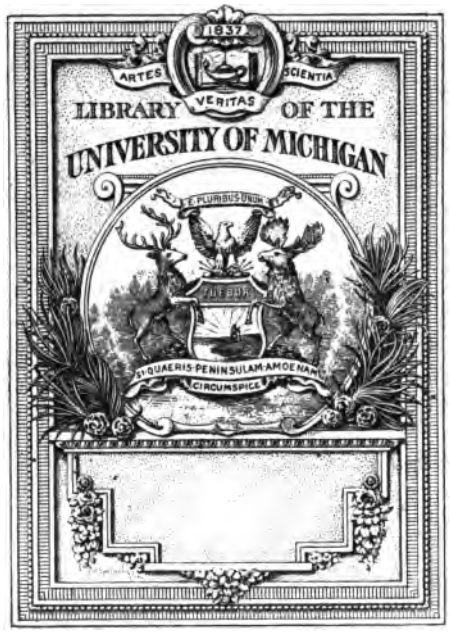
About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

B 1,060,894


1837
ARTES
VERITAS
SCIENTIA
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
E PLURIBUS UNUM
SI QUAERIS PENINSULAM AMOENAM
CIRCUMSPICE

Q
11
.A51pr


1837
ARTES
VERITAS
SCIENTIA
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
E PLURIBUS UNUM
SI QUAERIS PENINSULAM AMOENAM
CIRCUMSPICE

Q
11
.A51+

176

PROCEEDINGS

OF

THE AMERICAN ASSOCIATION

GENERAL LIBRARY University of MICHIGAN

FOR THE

ADVANCEMENT OF SCIENCE,

TWENTY-EIGHTH MEETING,

HELD AT

SARATOGA SPRINGS, N. Y.

AUGUST, 1879.

SALEM:
PUBLISHED BY THE PERMANENT SECRETARY.
1880.

EDITED BY

FREDERICK W. PUTNAM,

Permanent Secretary.

PRINTED AT

THE SALEM PRESS,

SALEM, MASS.

TABLE OF CONTENTS.

	PAGE
Officers of the Saratoga Meeting	vi
Committees of the Sections, Saratoga Meeting	vii
Local Committee of Saratoga Meeting	viii
Special Committees of the Association	x
Officers for the Boston Meeting	xii
Local Committee for Boston Meeting	xiii
Meetings of the Association of American Geologists and Naturalists	xv
Meetings of the Association	xvi
Act of Incorporation	xviii
Constitution of the Association	xix
Order of Proceedings in Organizing a Meeting	xxvii
Members of the Association:	
Patron	xxviii
Members	xxviii
Fellows	xlv
Deceased Members	lv

ADDRESS OF THE RETIRING PRESIDENT, O. C. MARSH 1

SECOND REPORT OF THE COMMITTEE ON AN INTERNATIONAL GEOLOGICAL CONGRESS 43

SECTION A. MATHEMATICS, PHYSICS AND CHEMISTRY.

Address of S. P. LANGLEY, Vice President 51

COMMUNICATIONS.

On the Observations of Double Stars. By ASAPH HALL 65

Observations on the Transit of Mercury, 1878, May 6, including a Systematic Search for a Satellite, and Measures of the Diameter of the Planet. By D. P. TODD 74

A Method of investigating the Errors produced by Irregularities in the Form of the Pivots of a Meridian Instrument. By C. A. YOUNG . . . 77
Discovery of the Coincidence of the Bright Lines of the Oxygen Spectrum with Bright Lines in the Solar Spectrum. By HENRY DRAPER. Illustrated 81
On the Color Correction of Achromatic Telescopes. By WM. HARKNESS . 96
Modern Star Places, with Suggestions relative to Future Cooperation among Meridian Observers. By LEWIS BOSS 106
Determination of Solar Parallax at the Oppositions of Minor Planets. By LEWIS BOSS 123
Experimental Determination of the Velocity of Light. By ALBERT A. MICHELSON. Illustrated 124
On the Conversion of Mechanical Energy into Heat by Dynamo-electric Machines. By GEORGE F. BARKER 160
On a Curious Case of Crystallization of Canada Balsam. By GEORGE F. BARKER. Illustrated 169
On the Phenomena of heating Metals in vacuo by means of an Electric Current. By THOS. A. EDISON 173
On a Resonant Tuning Fork. By THOMAS A. EDISON. Illustrated . . 178
Methods for Testing Faradic Machines. By FRANCIS R. UPTON . . . 178
On the First Results from a New Diffraction Ruling-Engine. By WM. A. ROGERS 184
An Experimental Solution of a Problem in the Doctrine of Chances. By T. C. MENDENHALL 190
On the Strength of American Timber. By R. H. THURSTON. Illustrated . 192
Titles of Papers read in the Section but not printed 209

PERMANENT SUBSECTION OF CHEMISTRY.

Address of IRA REMSEN, Chairman 213
Results of Systematic Analyses of Air, to determine the Cause of the Variations in the Amount of Oxygen therein contained. By EDW. W. MORLEY 229
On Some Details in the Construction of an Apparatus for the Analysis of Gases. By EDW. W. MORLEY 230
Preliminary Notice of a Revision of the Atomic Weights. By F. W. CLARKE 230
Note on a Peculiar Case of Corrosion of the Metal Tin. By J. W. OSBORNE 232
On the Sugar Content of the Sap of the Maple tree and the Pressure of the same. By H. W. WILEY 234
Chemical Notes. By ALBERT R. LEEDS 236
On the Limits of Meteorological Conditions Governing the Extension of Beet-root Culture. By WM. MCMURTRIE 242
Titles of Papers read in the Subsection, but not printed 248

SECTION B. NATURAL HISTORY.

Address of JOHN W. POWELL, Vice President 251

COMMUNICATIONS.

The History of some pre-Cambrian Rocks in America and Europe. By T. STERRY HUNT 279
Notice of the Occurrence of Rocks Representing the Marcellus Shale of New York, in Central Ohio. By R. P. WHITFIELD. Illustrated . . . 297

The Succession of Glacial Deposits in New England. By WARREN UPHAM 299
On the Geological Action of the Humus Acids. By ALEXIS A. JULIEN. Illustrated 311
On the Conditions to be filled by a Theory of Life. By CHARLES SEDGWICK MINOT 411
On the Occurrence of Microscopic Crystals in the Vertebra of the Toad (*Bufo Americanus*). By H. CARRINGTON BOLTON. With a Note by ALEXIS A. JULIEN. Illustrated 415
On Certain Forms of Muscæ Volitantes. By J. W. OSBORNE. Illustrated 419
The Inter-articular Ligament of the Head of the Ribs in the Cat. By S. H. GAGE 421
A New Method of demonstrating the Thoracic Duct in Animals. By S. H. GAGE 425
A Short Biography of the Menhaden. By G. BROWN GOODE 425
On the Species of Bornean Orangs, with Notes on their Habits. By WM. T. HORNADAY 438
Philosophy of the Pupation of Butterflies and particularly of the Nymphalidæ. By C. V. RILEY. Illustrated 455
The Cotton Worm in the United States. By C. V. RILEY 464
On a New Predaceous Lepidopterous Insect. By J. HENRY COMSTOCK. Illustrated 467
Some interesting Insect-habits and their Development. By W. S. BARNARD. Illustrated 472
The Bud-blight Insect. By W. S. BARNARD. Illustrated 478
Titles of other Papers read in the Section but not printed 487

PERMANENT SUBSECTION OF ANTHROPOLOGY.

The Sign Language of the North American Indians. By GARRICK MALLERY. Illustrated 493
On the Explanation of Hereditary Transmission. By LOUIS ELSBERG . 520
Monograph on Jade, illustrated with fine specimens of the different varieties. Abstract. By ERMINNIE A. SMITH 523
Description of a Polished Stone Implement found in Monkton, Vermont. By JOHN M. CURRIER. Illustrated. 526
Notes on the Archæology of the Champlain Valley. By GEORGE H. PERKINS 528
Titles of Papers read in the Subsection, but not printed 540

EXECUTIVE PROCEEDINGS.

Report of the General Secretary 541
General Report of the Permanent Secretary 563
Cash Account of the Permanent Secretary 566

INDEX.

CORRECTION.

In table on p. 204, under Mod. Rupture for Yellow Pine, make 20702.0 read: — 20.702

OFFICERS OF THE

SARATOGA MEETING.

PRESIDENT.

GEORGE F. BARKER, of Philadelphia.

VICE PRESIDENT, Section A.

S. P. LANGLEY, of Allegheny.

VICE PRESIDENT, Section B.

JOHN W. POWELL, of Washington.

CHAIRMAN OF PERMANENT SUBSECTION OF CHEMISTRY.

F. W. CLARKE,* of Cincinnati.

CHAIRMAN OF PERMANENT SUBSECTION OF MICROSCOPY.

EDWARD W. MORLEY, of Hudson, Ohio.

CHAIRMAN OF PERMANENT SUBSECTION OF ANTHROPOLOGY.

DANIEL WILSON, of Toronto.

PERMANENT SECRETARY.

F. W. PUTNAM, of Cambridge.

GENERAL SECRETARY.

H. CARRINGTON BOLTON,† of Hartford.

SECRETARY OF SECTION A.

JOHN K. REES, of St. Louis.

SECRETARY OF SECTION B.

W. H. DALL,‡ of Washington.

SECRETARY OF PERMANENT SUBSECTION OF CHEMISTRY.

W. R. NICHOLS, of Boston.

SECRETARY OF PERMANENT SUBSECTION OF MICROSCOPY.

A. B. HERVEY, of Taunton.

SECRETARY OF PERMANENT SUBSECTION OF ANTHROPOLOGY.

JOHN G. HENDERSON, of Winchester.

TREASURER.

WILLIAM S. VAUX,§ of Philadelphia.

* In the absence of IRA REMSEN, of Baltimore.
† In the absence of GEORGE LITTLE, of Atlanta.
‡ In the absence of A. G. WETHERBY, of Cincinnati.
§ Not present.

STANDING COMMITTEE.

Past Presidents.—BENJAMIN PEIRCE, of Cambridge; JAMES D. DANA,§ of New Haven; JAMES HALL, of Albany; STEPHEN ALEXANDER,§ of Princeton; ISAAC LEA,§ of Philadelphia; F. A. P. BARNARD, of New York; J. S. NEWBERRY,§ of New York; B. A. GOULD,§ of Boston; T. STERRY HUNT, of Montreal; ASA GRAY,§ of Cambridge; J. LAWRENCE SMITH,§ of Louisville; JOSEPH LOVERING, of Cambridge; JOHN L. LECONTE,§ of Philadelphia; J. E. HILGARD,§ of Washington; WILLIAM B. ROGERS, of Boston; SIMON NEWCOMB, of Washington.

The President, Vice Presidents, Four Secretaries and Treasurer.

Officers of the Preceding Meeting.—O. C. MARSH, of New Haven; R. H. THURSTON,§ of Hoboken; A. R. GROTE, of Buffalo; F. E. NIPHER,§ of St. Louis.

From the Association at large.—WILLIAM HARKNESS, of Washington; S. H. SCUDDER, of Cambridge; HENRY MORTON, of Hoboken; C. A. YOUNG, of Princeton; J. G. MORRIS, of Baltimore; F. W. CLARKE, of Cincinnati.

SECTIONAL COMMITTEE OF SECTION A.

A. W. WRIGHT, of New Haven.
JOHN TROWBRIDGE, of Cambridge.
W. A. ROGERS, of Cambridge.

SECTIONAL COMMITTEE OF SECTION B.

C. H. HITCHCOCK, of Hanover.
J. M. SAFFORD, of Nashville.
WILLIAM SAUNDERS, of London, Ontario.

NOMINATION COMMITTEE OF SECTION A.

W. H. PULSIFER, of St. Louis.
J. R. EASTMAN, of Washington.
JOHN TROWBRIDGE, of Cambridge.
P. W. SHEAFER, of Pottsville.

NOMINATION COMMITTEE OF SECTION B.

S. S. HALDEMAN, of Chickies.
C. H. HITCHCOCK, of Hanover.
E. A. DALRYMPLE, of Baltimore.
W. C. KERR, of Raleigh.

LOCAL COMMITTEE

OF THE

SARATOGA MEETING.

Chairman.— Dr. R. C. McEwen.

Treasurer.— Dr. J. L. Perry.

Secretary.— Prof. H. A. Wilson.

Corresponding Secretaries.— { Lt. Commander A. R McNair, and Prof. L. S. Packard.

SUBCOMMITTEES.

On Reception.— Gen. Winsor B. French, *Chairman;* Hon. A. Bockes, John Newland, Hon. C. S. Lester, Hon. Neil Gilmour, C. E. Leland, Hon. J. W. Crane, Col. S. A. Willoughby, Hon. E. H. Peters, Wm. C. Bronson, John A. Lee, A. Pond, Wm. B. Gage, Col. D. F. Ritchie, Rev. P. Stryker, Henry Clair, L. B. Pike, Hiram Tompkins, H. S. Clement, Dr. S. E. Strong, John R. Putnam, Rev. W. H. Hughes, Dr. T. B. Reynolds, Rev. B. Hawley, Prof. C. F. Dowd, W. A. Shepherd, Rev. G. P. Hawley, R. A. Heminway, Rev. J. Carey, Prof. H. E. Webster, Dr. R. H. Ward, Rev. Geo. Smith, Edward Selden, James M. Andrews, J. P. Butler, A. B. Olmsted, Rev. John McMenomy, Dr. S. J. Pearsall, Dr. W. H. Hall, Dr. C. F. Rich, Ransom Cook.

Albany Committee.—Hon. Michael N. Nolan, Hon. Thomas W. Olcott, Prof. James Hall, LL. D., Dr. George T. Stevens, Prof. J. A. Lintner, Matthew Hale, Esq., Robert H. Pruyn, LL. D., Samuel B. Woolworth, LL. D, Orlando Meads, Henry H. Martin, Thomas Hun, M. D., Charles M. Jenkins, Jacob S. Mosher, M. D., Charles E. Smith, Charles Van Benthuysen, J. Howard King, D. J. Pratt, St. Clair McKelway, William Barnes, Hon. Hamilton Harris, Lewis Boss, Arthur Bott, Paul F. Cooper, Erastus Corning, Hon. Eli Perry, Rt. Rev. W. C. Doane, Townsend Fondey, Maurice E. Veile, Henry A. Homes, LL. D., Prof. J. S. St. John, J. H. Van Antwerp, Hon. William L. Learned, Dudley Olcott, Prof. William G. Nowell, Samuel B. Ward, M. D., Verplanck Colvin, James T. Gardner, Hon. J. H. Ramsey, Hon. H. P. Peirson, E. P. Waterbury.

On Finance. — W. H. EUSTIS, *Chairman;* Dr. C. H. PAYN, A. W. SHEPHERD, GEORGE L. AMES, JOHN H. WALBRIDGE, JAMES R. CHAPMAN, C. H. TEFFT, Jr., P. PORTER WIGGINS, J. WILLARD LESTER.

On Excursions.— Lt. Commander A. R. MCNAIR, *Chairman;* Prof. H. B. NASON, Dr. R. H. WARD, Hon. N. B. SYLVESTER, WM. HAY BOCKES, Col. LEGRAND, B. CANNON, J. W. EHNINGER, VERPLANCK COLVIN, CYRUS BUTLER, JAMES T. GARDNER, CORNELIUS SHEEHAN, L. G. OLMSTEAD, LL.D.

On Railroads.— Hon. JAMES M. MARVIN, *Chairman;* Hon. WEBSTER WAGNER, THEODORE VOORHEES, I. V. BAKER, Hon. J. H. RAMSEY, C. E. DURKEE, Hon. H. B. PEIRSON, JOHN M. DAVISON.

On Printing. — C. C. LESTER, *Chairman;* E. R. STEVENS, T. CHESTER WALBRIDGE, C. H. STURGES, C. L. POND.

On Rooms.— Hon. JOSEPH BAUCUS, *Chairman;* THOMAS NOXON, L. H. CRAMER.

On Mails, Telegraph and Express.— Capt. B. F. JUDSON, *Chairman;* JOHN G. OWEN, HENRY SMITH.

Executive Committee.— The Officers, and the Chairmen of the several subcommittees.

OFFICERS OF THE ASSOCIATION

ELECTED FOR THE

BOSTON MEETING.

PRESIDENT.

Lewis H. Morgan, of Rochester, N. Y.

VICE PRESIDENT, Section A.

Asaph Hall, of Washington, D. C.

VICE PRESIDENT, Section B.

Alexander Agassiz, of Cambridge, Mass.

CHAIRMAN OF PERMANENT SUBSECTION OF CHEMISTRY.

John M. Ordway, of Boston, Mass.

CHAIRMAN OF PERMANENT SUBSECTION OF MICROSCOPY.

S. A. Lattimore, of Rochester, N. Y.

CHAIRMAN OF PERMANENT SUBSECTION OF ANTHROPOLOGY.

J. W. Powell, of Washington, D. C.

PERMANENT SECRETARY.

F. W. Putnam, of Cambridge, Mass.

GENERAL SECRETARY.

John K. Rees, of St. Louis, Mo.

SECRETARY OF SECTION A.

Henry B. Nason, of Troy, N. Y.

SECRETARY OF SECTION B.

C. V. Riley, of St. Louis, Mo.

SECRETARY OF SUBSECTION OF CHEMISTRY.

Charles E. Munroe, of Annapolis, Md.

SECRETARY OF SUBSECTION OF MICROSCOPY.

A. B. Hervey, of Taunton, Mass.

SECRETARY OF SUBSECTION OF ANTHROPOLOGY.

J. G. Henderson, of Winchester, Ill.

TREASURER.

William S. Vaux, of Philadelphia, Pa.

STANDING COMMITTEE.

Past Presidents.— Benjamin Peirce, of Cambridge; James D. Dana, of New Haven; James Hall, of Albany; Stephen Alexander, of Princeton; Isaac Lea, of Philadelphia; F. A. P. Barnard, of New York; J. S. Newberry, of New York; B. A. Gould, of Boston; T. Sterry Hunt, of Montreal; Asa Gray, of Cambridge; J. Lawrence Smith, of Louisville; Joseph Lovering, of Cambridge; John L. LeConte, of Philadelphia; J. E. Hilgard, of Washington; William B. Rogers, of Boston; Simon Newcomb, of Washington; O. C. Marsh, of New Haven.

The President, Vice Presidents, Permanent and General Secretaries, the Secretaries of Sections A and B, and Treasurer of the Meeting.

Officers of the Preceding Meeting.— George F. Barker, of Philadelphia; S. P. Langley, of Allegheny; J. W. Powell, of Washington; H. Carrington Bolton, of Hartford; W. H. Dall, of Washington.

From the Association at large.— Six Fellows to be elected on the first day of the meeting.

LOCAL COMMITTEE

FOR THE

BOSTON MEETING.

Chairman.

PROF. WILLIAM B. ROGERS.

Secretaries.

SAMUEL H. SCUDDER, Harvard College Library, Cambridge.
EDWARD BURGESS, Boston Society of Natural History.

Treasurer.

CHARLES W. SCUDDER, 69 Kilby Street, Boston.

Committee at Large: — Hon. Chas. Francis Adams; Dr. H. J. Bigelow; T. T. Bouvé; Dr. H. I. Bowditch; J. I. Bowditch; Hon. Wm. Claflin; Hon. S. C. Cobb; Hon. John Cummings; President C. W. Eliot; Dr. Samuel Eliot; George B. Emerson; Ralph Waldo Emerson; J. M. Forbes; Hon. Wm. Gaston; Prof. Asa Gray; Hon. Horace Gray; William Gray; Hon. E. R. Hoar; Dr. Oliver Wendell Holmes; H. P. Kidder; A. A. Lawrence; Hon. F. W. Lincoln; J. L. Little; Hon. John D. Long; Prof. Henry W. Longfellow; Prof. Joseph Lovering; Hon. John A. Lowell; Col. Theodore Lyman; Hon. E. R. Mudge; Hon. Otis Norcross; Francis Parkman; Prof. Benjamin Peirce; Hon. H. L. Peirce; Hon. F. O. Prince; Hon. Josiah Quincy; Hon. Alexander H. Rice; Hon. Thomas Talbot; Nathaniel Thayer; Hon. E. S. Tobey; Hon. J. M. Wightman; Hon. Marshall P. Wilder; Hon. Robert C. Winthrop; J. Huntington Wolcott.

Reception Committee:—Dr. S. L. Abbot; J. S. Amory; Nathan Appleton, *Secretary;* T. G. Appleton; W. S. Appleton; E. Austin; G. W. Bond; Hon. A. W. Beard; Hon. Martin Brimmer; Rev. Phillips Brooks; P. C. Brooks; J. Elliot Cabot; Dr. Samuel Cabot; Pres. E. H. Capen; Hon. Mellen Chamberlain; George B. Chase; Rev. James Freeman Clarke; Dr. B. E. Cotting; Charles Deane; R. H. Eddy; Henry Edwards; Dr. Calvin Ellis; Rev. George E. Ellis; J. T. Fields; Charles L. Flint; Hon. Dwight Foster; H. W. Fuller; Thomas Gaffield; W. W. Greenough; Rev. E. E. Hale; Hon. Alpheus Hardy; Franklin Haven; Capt. M. Haxtun, U. S. N.; George Higginson; Dr. R. M. Hodges; Dr. R. W. Hooper; H. H. Hunnewell; M. P. Kennard; Col. T. T. S. Laidley, U. S. A.; Abbott Lawrence; Col. Henry Lee; Dr. G. H. Lodge; Gen. Charles G. Loring; Augustus Lowell; Rev. J. M. Manning; J. J. May; Thomas Motley; Prof. J. K. Paine; O. W. Peabody; C. C. Perkins; J. C. Phillips; W. D. Pickman; Mayor F. O. Prince, *Chairman;* Commodore G. M. Ransom, U. S. N.; G. C. Richardson; H. B. Rogers; John C. Ropes; B. S. Rotch; Hon. Leverett Saltonstall; Prof. C. S. Sargent; Barthold Schlesinger; G. O. Shattuck; Dr. Benjamin S. Shaw; Quincy A. Shaw; Dr. D. D. Slade; S. B. Stebbins; Dr. D. H. Storer; G. W. Wales; Dr. C. E. Ware; S. D. Warren; Pres. W. F. Warren; Rev. R. C. Waterston; E. P. Whipple; Dr. J. C. White; Dr. H. W. Williams; Roger Wolcott; Dr. E. S. Wood; Mrs. Louis Agassiz; Mrs. Ednah D. Cheney; Miss Lucretia Crocker; Miss Cora Clarke; Mrs. James T. Fields; Miss Ellen Frothingham; Miss Susan Hale; Mrs. Augustus Hemenway; Mrs. S. T. Hooper; Mrs. Julia Ward Howe; Mrs. Phebe M. Kendall; Mrs. Jonathan A. Lane; Mrs. J. E. Lodge; Miss Abby W. May; Mrs. R. H. Richards; Mrs. C. C. Smith; Miss Ticknor; Mrs. S. D. Warren; Mrs. Kate Gannett Wells.

Committee on Finance:— Dr. Robert Amory; Hon. John Cummings, *Chairman;* William Endicott; Augustus Flagg; W. O. Grover; Franklin Haven; George Higginson; Hamilton A. Hill; E. W. Hooper; H. P. Kidder; J. L. Little; Augustus Lowell; Hon. E. R. Mudge; Gen. Francis

A. Osborn; C. J. Paine; F. E. Parker; F. H. Peabody; Gen. C. L. Peirson; Gen. A. P. Rockwell; M. D. Ross; Charles W. Scudder; Charles James Sprague; Nathaniel Thayer; Samuel Wells, *Secretary*.

Committee on Railroads:—C. F. Adams, Jr.; Edward Atkinson; Dr. J. R. Chadwick, *Secretary;* C. F. Choate; Hon. John Cummings; Dr. C. F. Folsom; C. W. Folsom; William T. Hart; Franklin Haven; Dr. B. Joy Jeffries; B. P. Mann; Gen. Francis A. Osborn; E. B. Phillips; Gen. A. P. Rockwell, *Chairman;* J. B. Stearns; James P. Tolman.

Committee on Hotels and Lodgings:—Dr. W. S. Bigelow; E. T. Bouvé, *Secretary;* F. C. Bowditch; N. J. Bradlee; Edw. Burgess; Dr. John Dixwell; Prof. A. E. Dolbear; Dr. W. G. Farlow; R. C. Greenleaf; Curtis Guild; G. W. Hammond; J. B. Henck, Jr.; Dr. David Hunt; Prof. C. L. Jackson; Prof. G. F. H. Markoe; Prof. John P. Marshall; Dr. C. S. Minot; Gen. Francis A. Osborn, *Chairman;* Prof. G. A. Osborne; A. S. Porter; H. A. Purdie; Dr. Thomas M. Rotch; S. P. Ruggles; S. P. Sharples; Dr. F. C. Shattuck: Dr. J. C. Warren; Prof. William Watson; Dr. W. F. Whitney; Prof. C. Whittaker.

Committee on Rooms for Meetings:—Prof. W. P. Atkinson; L. S. Burbank; Edw. Burgess; W. O. Crosby; Prof. C. R. Cross; Prof. F. H. Howison; Prof. A. Hyatt; Prof. G. Lanza; Prof. W. R. Nichols; Prof. J. M. Ordway, *Chairman;* Prof. C. P. Otis; Prof. R. H. Richards, *Secretary;* E. P. Seaver; Homer B. Sprague; Prof. W. R. Ware; Prof. C. H. Wing.

Committee on Mails, Express and Telegraph:—Waldo Adams; Prof. A. Graham Bell; Dr. Clarence J. Blake, *Secretary;* F. C. Bowditch; George L. Bradley; Col. W. W. Clapp; Prof. C. R. Cross, *Chairman;* James Eggleston; Col. William H. Forbes; D. A. Goddard; E. L. Godkin; E. B. Haskell; Col. T. W. Higginson; W. A. Hovey; Gardiner G. Hubbard; George F. Milliken; Patrick T. Jackson; Col. R. M. Pulsifer; Waldo O. Ross; M. E. Wadsworth; Dr. G. F. Waters; R. Worthington.

Committee on Excursions:—Edward Atkinson, *Chairman;* Ernest W. Bowditch; Dr. Henry P. Bowditch, *Secretary;* C. H. Dalton; W. M. Davis, Jr.; Dr. John Dean; Dr. Thomas Dwight; Dr. R. T. Edes; J. Rayner Edmands; R. B. Forbes; James B. Francis; Dr. Samuel A. Green; Prof. H. W. Haynes; Prof. J. B. Henck; Hamilton A. Hill; Dr. S. Kneeland; H. F. Mills; Prof. Henry Mitchell; Prof. William H. Niles; Gen. F. W. Palfrey; S. R. Payson; E. S. Philbrick; J. D. Philbrick; Dr. C. P. Putnam; Dr. J. J. Putnam; Dr. H. P. Quincy: Col. H. S. Russell; C. S. Storrow; Dr. J. C. Warren; Prof. H. L. Whiting; Dr. Edward Wigglesworth; Dr. C. H. Williams.

Cambridge Committee:—A. Agassiz, *Chairman;* Lucien Carr; Prof. William Cook; Prof. J. P. Cooke; Pres. C. W. Eliot; Prof. H. L. Eustis; Dr. W. G. Farlow; Prof. Wolcott Gibbs; Dr. G. L. Goodale; Prof. Asa Gray; Dr. H. A. Hagen; Prof. E. N. Horsford; Prof. Joseph Lovering; Prof. Benjamin Peirce; Prof. E. C. Pickering, *Secretary;* F. W. Putnam; Prof. W. A. Rogers: S. H. Scudder; Arthur Searle; Prof. N. S. Shaler; Prof. John Trowbridge; Sereno Watson; Prof. C. J. White; Prof. J. D. Whitney; Justin Winsor; Dr. Morrill Wyman.

Salem Committee:—Rev. E. S. Atwood; Rev. Edwin C. Bolles; James H. Emerton; George R. Emmerton; Hon. William C. Endicott; Abner C. Goodell, Jr.; Daniel B. Hagar; Thomas F. Hunt; Rev. Fielder Israel; Dr. Amos H. Johnson; Frank R. Kimball; Hon. James Kimball; Hon. Otis P. Lord: Dr. William Mack; Richard C. Manning, *Secretary;* Prof. Edward S. Morse; Gen. Henry K. Oliver; Francis Peabody; S. Endicott Peabody; David Pingree; Robert S. Rantoul; John Robinson; Jacob C. Rogers; Gen. William Sutton; Dr. Henry Wheatland, *Chairman;* Hon. Stephen G. Wheatland; Capt. George M. Whipple.

Executive Committee:—Messrs. William B. Rogers; F. W. Putnam; C. W. Scudder; S. H. Scudder; E. Burgess, with the Chairman and Secretaries of the several special committees.

SPECIAL COMMITTEES.

1. *Permanent Committee on Weights, Measures and Coinage.*

F. A. P. BARNARD, of New York,
B. A. GOULD, of Boston,
J. E. HILGARD, of Washington,
H. A. NEWTON, of New Haven,
BENJAMIN PEIRCE, of Cambridge,
WILLIAM B. ROGERS, of Boston,
J. LAWRENCE SMITH, of Louisville,
E. B. ELLIOTT, of Washington,
JOHN TROWBRIDGE, of Cambridge,
A. M. MAYER, of Hoboken.

2. *Committee to Memorialize the Legislature of New York for a New Survey of Niagara Falls.*

F. A. P. BARNARD, of New York,
JAMES HALL, of Albany,
G. W. HOLLEY, of Niagara Falls,
J. T. GARDNER, of Albany.

3. *Committee to Memorialize Congress and State Legislatures regarding the Cultivation of Timber, and the Preservation of Forests.*

F. B. HOUGH, of Lowville,
ASA GRAY, of Cambridge,
G. B. EMERSON, of Boston,
J. D. WHITNEY, of Cambridge,
J. S. NEWBERRY, of Cleveland,
L. H. MORGAN, of Rochester,
CHAS. WHITTLESEY, of Cleveland,
W. H. BREWER, of New Haven,
E. W. HILGARD, of Berkeley.

4. *Committee on International Congress of Geologists.*

JAMES HALL, of Albany,
WILLIAM B. ROGERS, of Boston,
J. W. DAWSON, of Montreal,
J. S. NEWBERRY, of New York,
T. STERRY HUNT, of Montreal,
C. H. HITCHCOCK, of Hanover,
RAPHAEL PUMPELLY, of Owego,
J. P. LESLEY, of Philadelphia.

5. *Committee to Memorialize Congress in relation to the Yellowstone National Park.*

T. B. COMSTOCK, of Ithaca,
O. C. MARSH, of New Haven,
GEO. M. WHEELER, of Washington,
J. W. POWELL, of Washington,
CLARENCE KING, of New York.

6. *Committee on the Relation of Science to the Industrial Arts.*

R. H. THURSTON, of Hoboken,
J. M. SAFFORD, of Nashville,
J. T. WILDER, of Chattanooga,
O. CHANUTE, of New York,
J. W. OSBORNE, of Washington.

7. *Committee to Memorialize Congress in relation to Meteorological Researches.*

ELIAS LOOMIS, of New Haven,
N. S. SHALER, of Cambridge,
G. HINRICHS, of Iowa City,
J. B. KILLEBREW, of Nashville,
J. W. OSBORNE, of Washington.

8. *Committee to obtain Permanent Funds for the Association, and to advise with Treasurer and Permanent Secretary on financial matters.*

WM. B. ROGERS, of Boston,
J. LAWRENCE SMITH, of Louisville,
LEWIS H. MORGAN, of Rochester,
ALEXANDER AGASSIZ, of Cambridge,
ROBERT H. THURSTON, of Hoboken.

9. *Committee on Membership.*

J. S. NEWBERRY, of New York,
SIMON NEWCOMB, of Washington,
WILLIAM B. ROGERS, of Boston,
J. D. DANA, of New Haven,
J. LAWRENCE SMITH, of Louisville,
The GENERAL SECRETARY,
The PERMANENT SECRETARY.

10. *Committee on Science Teaching in the Public Schools.*

E. L. YOUMANS, of New York,
A. R. GROTE, of Buffalo,
J. W. POWELL, of Washington,
N. S. SHALER, of Cambridge,
J. S. NEWBERRY, of New York.

11. *Committee to Audit the Accounts of the Permanent Secretary and Treasurer.*

HENRY WHEATLAND, of Salem,
THOMAS MEEHAN, of Philadelphia.

MEETINGS AND OFFICERS OF THE AMERICAN ASSOCIATION OF GEOLOGISTS AND NATURALISTS.

MEETING.	DATE.	PLACE.	CHAIRMAN.	SECRETARY.	ASSIST. SEC'Y.	TREASURER.
1st	April 2. 1840,	Philadelphia,	Edward Hitchcock,*	L. C. Beck,*		
2d	April 5, 1841,	Philadelphia,	Benjamin Silliman,*	L. C. Beck,*	B. Silliman, jr., C. B. Trego,	
3d	April 25, 1842,	Boston,	S. G. Morton,*	C. T. Jackson,	J. D. Whitney, M. B. Williams,	
4th	April 26, 1843,	Albany,	Henry D. Rogers,*	B. Silliman, jr.,		John Locke.*
5th	May 8, 1844,	Washington,	John Locke,*	B. Silliman, jr., O. P. Hubbard,		Douglas Houghton.*
6th	April 30, 1845,	New Haven,	Wm. B. Rogers,	B. Silliman, jr., J. Lawrence Smith,		Douglas Houghton.*
7th	Sept. 2. 1846,	New York,	C. T. Jackson,	B. Silliman, jr.,		E. C. Herrick.*
8th	Sept. 20, 1847,	Boston,	Wm. B. Rogers,†	Jeffries Wyman,*		B. Silliman, jr.

*Deceased.

†Professor ROGERS, as chairman of this last meeting, called the first meeting of the new Association to order and presided until it was fully organized by the adoption of a constitution. As he was thus the first presiding officer of the new Association, it was directed at the Hartford meeting that his name be placed at the head of the Past Presidents of the American Association for the Advancement of Science.

MEETINGS AND OFFICERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

MEETING.	DATE.	PLACE.	PRESIDENT.	VICE-PRESIDENT.	GENERAL SECRETARY.	PERMANENT SEC'Y.	TREASURER.
1st	Sept. 20, 1848.	Philadelphia, Pa.,	W. C. Redfield.*		Walter R. Johnson,*		Jeffries Wyman.*
2d	Aug. 11, 1849.	Cambridge, Mass.,	Joseph Henry,*		E. N. Horsford, 1		A. L. Elwyn.
3d	Mar 12, 1850.	Charleston, S. C.,	A. D. Bache,* 2		L. R. Gibbs, 3		St. J. Ravenel.* 4
4th	Aug. 19, 1850.	New Haven, Conn.,	A. D. Bache,*		E. C. Herrick,*		A. L. Elwyn.
5th	May 5, 1851.	Cincinnati, Ohio,	A. D. Bache,*		W. B. Rogers, 5	S. F. Baird,	S. F. Baird. 6
6th	Aug. 19, 1851.	Albany, N. Y.,	Louis Agassiz,*		W. B. Rogers,	S. F. Baird,	A. L. Elwyn.
7th	July 28, 1853.	Cleveland, Ohio,	Benjamin Pierce,		S. St. John, 7	S. F. Baird,	A. L. Elwyn.
8th	April 26 1854.	Washington, D.C.,	J. D Dana,		J. Lawrence Smith,	Joseph Lovering,	J. L. LeConte. 8
9th	Aug. 15, 1855.	Providence, R. I.,	John Torrey,*		Wolcott Gibbs,	Joseph Lovering,	A. L. Elwyn.
10th	Aug. 20, 1856.	Albany, N. Y.,	James Hall,		B. A. Gould,	Joseph Lovering,	A. L. Elwyn.
11th	Aug. 12, 1857.	Montreal, Canada.	Alexis Caswell.* 9	Alexis Caswell.*	John LeConte,	Joseph Lovering,	A. L. Elwyn.
12th	April 28, 1858.	Baltimore, Md.,	Alexis Caswell.* 10	John E. Holbrook,*†	W. M. Gillespie.* 11	Joseph Lovering,	A. L. Elwyn.
13th	Aug. 3, 1859.	Springfield, Mass.,	Stephen Alexander,	Edward Hitchcock,*	William Chauvenet,*	Joseph Lovering,	A. L. Elwyn.
14th	Aug. 1. 1860	Newport, R. I.,	Isaac Lea,	B. A. Gould,	Joseph LeConte,	Joseph Lovering,	A. L. Elwyn.
15th	Aug. 15, 1866.	Buffalo, N. Y.,	F. A. P. Barnard,	A. A. Gould,* 12	Elias Loomis, 13	Joseph Lovering,	A. L. Elwyn.†
16th	Aug. 21, 1867.	Burlington, Vt.,	J. S. Newberry,	Wolcott Gibbs,	C. S. Lyman,	Joseph Lovering,	A. L. Elwyn.†
17th	Aug. 5, 1868.	Chicago, Ill.,	B. A. Gould,	Charles Whittlesey,	Simon Newcomb, 14	Joseph Lovering,	A. L. Elwyn.†
18th	Aug. 18, 1869.	Salem, Mass.,	J. W. Foster,*	O. N. Rood,	O. C. Marsh,	F. W. Putnam, 15	A. L. Elwyn.†
19th	Aug. 17, 1870.	Troy, N. Y.,	T. S. Hunt, 16	T. S. Hunt,	F. W. Putnam, 17	Joseph Lovering,	A. L. Elwyn.†
20th	Aug. 16, 1871.	Indianapolis, Ind.,	Asa Gray,	G. F. Barker,	F. W. Putnam,	Joseph Lovering,	W. S. Vaux.
21st	Aug. 15, 1872.	Dubuque, Iowa,	J. Lawrence Smith,	Alex. Winchell,	E. S. Morse,	Joseph Lovering,	W. S. Vaux.
22d	Aug. 20, 1873	Portland, Me.,	Joseph Lovering,	A. H. Worthen,†	C. A. White,	F. W. Putnam,	W. S. Vaux.
23d	Aug. 12, 1874.	Hartford, Conn.,	J. L. LeConte,	C. S. Lyman,	A. C. Hamlin,	F. W. Putnam.	W. S. Vaux.†

1. In place of Jeffries Wyman, *not present.*
2. In place of Joseph Henry, *not present.*
3. In place of E. C. Herrick, *not present.*
4. In place of A. L. Elwyn, *not present.*
5. In place of E. C. Herrick, *not present.*
6. In place of A. L. Elwyn, *not present.*
7. In place of J. D. Dana, *not present.*
8. In place of A. L. Elwyn, *not present.*
9. In place of J. W. Bailey, *deceased.*
10. In place of Jeffries Wyman, *not present.*
11. In place of Wm. Chauvenet, *not present.*
12. In place of R. W. Gibbes, *not present.*
13. In place of W. P. Trowbridge, *not present.*
14. In place of A. P. Rockwell, *called home 1st day.*
15. In place of Joseph Lovering, *in Europe.*
16. In place of Wm. Chauvenet, *too ill to be present.*
17. In place of C. F. Hartt, *in Brazil.*

* Deceased. † Not present at the meeting.

MEETINGS AND OFFICERS OF THE ASSOCIATION (*Continued*).

MEETING.	DATE.	PLACE.	PRESIDENT.	VICE PRESIDENT, SECTION A.
24th	Aug. 11, 1875,	Detroit, Mich.,	J. E. Hilgard,	H. A. Newton,
25th	Aug. 23, 1876,	Buffalo, N. Y.,	William B. Rogers,	Charles A. Young,
26th	Aug. 29, 1877,	Nashville, Tenn.,	Simon Newcomb,	R. H. Thurston,[1]
27th	Aug. 21, 1878,	St. Louis, Mo.,	O. C. Marsh,	R. H. Thurston,
28th	Aug. 27, 1879.	Saratoga, N. Y.	G. F. Barker,	S. P. Langley,

VICE PRESIDENT, SECTION B.	CHAIRMAN OF PERMANENT SUBSECTION C, CHEMISTRY.	CHAIRMAN OF PERMANENT SUBSECTION D, ANTHROPOLOGY.	CHAIRMAN OF PERMANENT SUBSECTION E, MICROSCOPY.
J. W. Dawson,	S. W. Johnson,	L. H. Morgan,	—— ——
Edward S. Morse,	George F. Barker,	L. H. Morgan,	R. H. Ward,
O. C. Marsh,	N. T. Lupton,	Daniel Wilson,*	R. H. Ward,
Aug. R. Grote,	F. W. Clarke,	—— ——[2]	R. H. Ward,[3]
J. W. Powell,	F. W. Clarke,[4]	Daniel Wilson,	E. W. Morley,

PERMANENT SECRETARY.	GENERAL SECRETARY.	SECRETARY OF SECTION A.	SECRETARY OF SECTION B.
F. W. Putnam,	S. H. Scudder,	S. P. Langley, T. C. Mendenhall,	E. S. Morse,
F. W. Putnam,	T. C. Mendenhall,	A. W. Wright,	Albert H. Tuttle,
F. W. Putnam,	Aug. R. Grote,	H. C. Bolton,	Wm. H. Dall,
F. W. Putnam,	H. C. Bolton,	F. E. Nipher,	George Little,
F. W. Putnam,	H. C. Bolton,[5]	J. K. Rees,	W. H. Dall,[6]

SECRETARY OF PERMANENT SUBSECTION C, CHEMISTRY.	SECRETARY OF PERMANENT SUBSECTION D, ANTHROPOLOGY.	SECRETARY OF PERMANENT SUBSECTION E, MICROSCOPY.	TREASURER.
F. W. Clarke,	F. W. Putnam,	—— ——	W. S. Vaux.
H. C. Bolton,	O. T. Mason,	E. W. Morley,	W. S. Vaux.
P. Schweitzer,	—— —— ——[2]	T. O. Summers, jr.,	W. S. Vaux.*
A. P. S. Stuart,	—— ——[2]	Geo. J. Engelmann,	W. S. Vaux.*
W. R. Nichols,	J. G. Henderson,	A. B. Hervey,	W. S. Vaux.*

[1] In the absence of E. C. Pickering.
[2] The Subsection united with Sec. B.
[3] In the absence of G. S. Blackie.
[4] In the absence of Ira Remsen.
[5] In the absence of George Little.
[6] In the absence of A. C. Wetherby.
*Not present.

COMMONWEALTH OF MASSACHUSETTS.

IN THE YEAR ONE THOUSAND EIGHT HUNDRED AND SEVENTY-FOUR.

AN ACT

To Incorporate the "American Association for the Advancement of Science."

Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows:

Section 1. Joseph Henry of Washington, Benjamin Pierce of Cambridge, James D. Dana of New Haven, James Hall of Albany, Alexis Caswell of Providence, Stephen Alexander of Princeton, Isaac Lea of Philadelphia, F. A. P. Barnard of New York, John S. Newberry of Cleveland, B. A. Gould of Cambridge, T. Sterry Hunt of Boston, Asa Gray of Cambridge, J. Lawrence Smith of Louisville, Joseph Lovering of Cambridge and John LeConte of Philadelphia, their associates, the officers and members of the Association, known as the "American Association for the Advancement of Science," and their successors, are hereby made a corporation by the name of the "American Association for the Advancement of Science," for the purpose of receiving, purchasing, holding and conveying real and personal property, which it now is, or hereafter may be possessed of, with all the powers and privileges, and subject to the restrictions, duties and liabilities set forth in the general laws which now or hereafter may be in force and applicable to such corporations.

Section 2. Said corporation may have and hold by purchase, grant, gift or otherwise, real estate not exceeding one hundred thousand dollars in value, and personal estate of the value of two hundred and fifty thousand dollars.

Section 3. Any two of the corporators above named are hereby authorized to call the first meeting of the said corporation in the month of August next ensuing, by notice thereof "by mail," to each member of the said Association.

Section 4. This act shall take effect upon its passage.

House of Representatives, March 10, 1874.
Passed to be enacted,
John E. Sanford, *Speaker.*

In Senate, March 17, 1874.
Passed to be enacted,
Geo. B. Loring, *President.*

March 19, 1874.
Approved,
W. B. Washburn.

Secretary's Department,
Boston, April 3, 1874.
A true copy, Attest:
David Pulsifer,
Deputy Secretary of the Commonwealth.

CONSTITUTION

OF THE

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Incorporated by Act of the General Court of the Commonwealth of Massachusetts.

OBJECTS.

ARTICLE 1. The objects of the Association are, by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of America, to give a stronger and more general impulse and more systematic direction to scientific research, and to procure for the labors of scientific men increased facilities and a wider usefulness.

MEMBERS, FELLOWS, PATRONS AND HONORARY FELLOWS.

ART. 2. The Association shall consist of Members, Fellows, Patrons and Honorary Fellows.

ART. 3. Any person may become a Member of the Association upon recommendation in writing by two members or fellows, nomination by the Standing Committee, and election by a majority of the members and fellows present in general session.

ART. 4. Fellows shall be nominated by the Standing Committee from such of the members as are professionally engaged in science, or have by their labors aided in advancing science. The election of fellows shall be by ballot and a majority vote of the members and fellows present in general session. But all persons who may be members at the time of the adoption of this constitution may become fellows by signifying their desire to this effect before the first day of August, 1875.

ART. 5. Any person paying to the Association the sum of one thousand dollars shall be classed as a Patron, and shall be entitled to all the privileges of a member and to all its publications.

ART. 6. Honorary Fellows of the Association, to the number of ten for each section, may be elected; the nominations to be made by the Standing Committee and approved by ballot in the respective sections before election by ballot in general session. Honorary Fellows shall be entitled to all the privileges of fellows and shall be exempt from all fees and assessments, and entitled to all publications of the Association issued after the date of their election.

ART. 7. The name of any member or fellow two years in arrears for annual dues shall be erased from the list of the Association, provided that two notices of indebtedness, at an interval of at least three months, shall have been given; and no such person shall be restored until he has paid his arrearages or has been reëlected.

ART. 8. No member or fellow shall take part in the organization or business of both sections at the same meeting.

OFFICERS.

ART. 9. The Officers of the Association shall be elected by ballot in general session from the fellows and shall consist of a President, two Vice Presidents, a General Secretary, a Permanent Secretary, a Treasurer, a Secretary of Section A, and a Secretary of Section B; these, with the exception of the Permanent Secretary, shall be elected at each meeting for the following one, and, with the exception of the Treasurer and the Permanent Secretary, shall not be reëligible for the next two meetings. The Permanent Secretary shall be elected at each fifth meeting.

ART. 10. The President, or, in his absence, one of the Vice Presidents, shall preside at all general sessions of the Association and at all meetings of the Standing Committee. It shall also be the duty of the President to give an address at a general session of the Association at the meeting following that over which he presided.

ART. 11. The Vice Presidents shall be the presiding officers of Sections A and B, and of the Sectional Committees, and it shall be part of their duty to give an address, each before his respective section, at such time as the section shall determine. The Vice Presidents may request their respective sections to appoint temporary chairmen to preside over the sessions of the sections, but shall not delegate their other duties.

ART. 12. The General Secretary shall be the Secretary of all general sessions of the Association, and of all sessions of the Standing Committee, and shall keep a record of the business of these sessions. He

shall receive the records from the Secretaries of the Sections, which, after examination, he shall transmit with his own records to the Permanent Secretary within two weeks after the adjournment of the meeting. He shall receive proposals for membership and bring them before the Standing Committee. He shall give to the Secretary of each Section the list of papers assigned to it by the Standing Committee.

ART. 13. The Permanent Secretary shall be the executive officer of the Association under the direction of the Standing Committee. He shall attend to all business not specially referred to committees nor otherwise constitutionally provided for. He shall keep an account of all business that he has transacted for the Association, and make annually at the first meeting of the Standing Committee, a report which shall be laid before the Association. He shall attend to the printing and distribution of the annual volume of Proceedings, and all other printing ordered by the Association. He shall issue a circular of information to members and fellows at least four months before each meeting, and shall, in connection with the Local Committee, make all necessary arrangements for the meetings of the Association. He shall provide the Secretaries of the Association with such books and stationery as may be required for their records and business, and shall provide members and fellows with such blank forms as may be required for facilitating the business of the Association. He shall collect all assessments and admission fees, and notify members and fellows of their election, and of any arrearages. He shall receive, and bring before the Standing Committee, the titles and abstracts of papers proposed to be read before the Association. He shall keep an account of all receipts and expenditures of the Association, and report the same annually at the first meeting of the Standing Committee, and, at the close of each year, shall pay over to the Treasurer such unexpended funds as the Standing Committee may direct. He shall receive and hold in trust for the Association all books, pamphlets and manuscripts belonging to the Association, and allow the use of the same under the provisions of the Constitution and the orders of the Standing Committee. He shall receive all communications addressed to the Association during the interval between meetings, and properly attend to the same. He shall at each meeting report the names of fellows and members who have died since the preceding meeting. He shall be allowed a salary which shall be determined by the Standing Committee, and may employ a clerk at such compensation as may be agreed upon by the Standing Committee.

ART. 14. The Treasurer shall invest the funds received by him in such securities as may be directed by the Standing Committee. He shall annually present to the Standing Committee an account of the funds in his charge. No expenditure of the principal in the hands of the Treasurer shall be made without a unanimous vote of the Standing Committee, and no expenditure of the income received by the Treasurer shall be made without a two-thirds vote of the Standing Committee.

ART. 15. The Secretaries of Sections A and B shall keep the records of their respective sections, and, at the close of the meeting, give the same, including the records of subsections, to the General Secretary. They shall also be the secretaries of the sectional committees.

ART. 16. In case of a vacancy in the office of the President, one of the Vice Presidents shall be elected by the Standing Committee as the President of the meeting. Vacancies in the offices of Vice President, General Secretary, Permanent Secretary and Treasurer, shall be filled by nomination of the Standing Committee and election by ballot in general session. A vacancy in the office of Secretary of a Section shall be filled by nomination and election by ballot in the section.

ART. 17. The Standing Committee shall consist of the past Presidents, the President, the Vice Presidents, the four Secretaries, the Treasurer, with the above named officers of the preceding meeting, and six fellows elected by ballot after open nomination at the first general session. The members present at any regularly called meeting of the Committee, provided there are at least five, shall form a quorum for the transaction of business. The Standing Committee shall meet on the day preceding each annual meeting of the Association, and arrange the programme for the first day of the sessions. The time and place of this first meeting shall be designated by the Permanent Secretary. Unless otherwise agreed upon, regular meetings of the Committee shall be held in the committee room at 9 o'clock, A.M., on each day of the meeting of the Association. Special meetings of the Committee may be called at any time by the President. The Standing Committee shall be the board of supervision of the Association, and no business shall be transacted by the Association that has not first been referred to, or originated with, the Committee. The special business of the Committee shall be: to receive and assign papers to the respective sections; to examine and, if necessary, to exclude papers; to decide which papers, discussions and other proceedings shall be published, and to have the general direction of

the publications of the Association; to manage the financial affairs of the Association; to arrange the business and programmes for general sessions; to appoint general sessions for the evening; to suggest subjects for discussion, investigation or reports; to nominate members and fellows; to receive and act upon all invitations extended to the Association and report the same at a general session of the Association.

ART. 18. The Nominating Committee shall consist of the Standing Committee, and four members or fellows elected by each of the sections. It shall be the duty of this Committee to meet at the call of the President and nominate the general officers for the following meeting of the Association. It shall also be the duty of this Committee to recommend the time and place for the next meeting. The Vice Presidents and Secretaries of the Sections shall be recommended to the Nominating Committee by sub-committees consisting of the Vice Presidents and Secretaries, and the four persons elected by each section under the first clause of this article.

MEETINGS.

ART. 19. The Association shall hold public meetings annually, for one week or longer, at such time and place as may be determined by vote of the Association, and the preliminary arrangements for each meeting shall be made by the Local Committee, in conjunction with the Permanent Secretary and such other persons as the Standing Committee may designate.

ART. 20. General Sessions shall be held at 10 o'clock, A. M., unless otherwise ordered, on every day of the meeting, Sunday excepted, and at such other times as may be appointed by the Standing Committee.

SECTIONS AND SUBSECTIONS.

ART. 21. The Association shall be divided into two Sections, namely: **A** (*Mathematics*, *Astronomy*, *Physics*, *Chemistry* and *Mineralogy*) and **B** (*Geology*, *Zoology*, *Botany* and *Anthropology*). Either Section may, at its pleasure, form temporary or permanent subsections for the reading of papers.

ART. 22. Immediately on the organization of a Section there shall be three fellows elected by ballot after open nomination, who, with the Vice President and Secretary, and the Chairman and Secretary of the subsections, shall form its Sectional Committee. The Sectional Com-

mittees shall have power to fill vacancies in their own numbers. There shall be no sectional meeting during a general session.

ART. 23. When any Subsection organizes, it shall elect a Chairman and Secretary and report the result to the Secretary of its Section. The Secretary of a Subsection shall, at the close of the meeting, transmit his records to the Secretary of the Section. Any Permanent Subsection may elect its Chairman for the ensuing meeting.

ART. 24. No paper shall be read in any Section or Subsection until it has been placed on the programme of the day by the Sectional Committees.

SECTIONAL COMMITTEES.

ART. 25. The Sectional Committees shall arrange and direct the business of their respective sections. They shall prepare the daily programmes and give them to the Permanent Secretary for printing at the earliest moment practicable. No titles of papers shall be entered on the daily programmes except such as have passed the Standing Committee. No change shall be made in the programme for the day without the consent of the Sectional Committee. The Sectional Committees may refuse to place the title of any paper on the programme; but every such title, with the abstract of the paper or the paper itself must be returned to the Standing Committee with the reasons why it was refused.

ART. 26. The Sectional Committees shall examine all papers and abstracts referred to the sections, and they shall not place on the programme any paper inconsistent with the character of the Association; and to this end they have power to call for any paper, the character of which may not be sufficiently understood from the abstract submitted.

PAPERS AND COMMUNICATIONS.

ART. 27. All members and fellows must forward to the Permanent Secretary, as early as possible, and when practicable before the convening of the Association, full titles of all the papers which they propose to present during the meeting, with a statement of the time that each will occupy in delivery, and also such abstracts of their contents as will give a general idea of their nature; and no title shall be referred by the Standing Committee to the Sectional Committee until an abstract of the paper or the paper itself has been received.

ART. 28. If the author of any paper be not ready at the time assigned, the title may be dropped to the bottom of the list.

Reports of Meetings.

Art. 29. Whenever practicable, the proceedings and discussions at general sessions, sections and subsections shall be reported by professional reporters, but such reports shall not appear in print as the official reports of the Association unless revised by the secretaries.

Printed Proceedings.

Art. 30. The Permanent Secretary shall have the Proceedings of each meeting printed in an octavo volume as soon after the meeting as possible, beginning one month after adjournment. Authors must prepare their papers ready for the press and forward them to the Permanent Secretary within this interval, otherwise only the abstracts or titles will appear in the printed volumes. The Standing Committee shall have power to print an abstract only of any paper. Whenever practicable, proofs shall be forwarded to authors for revision. If any additions or substantial alterations are made by the author of a paper after its submission to the Secretary, the same shall be distinctly indicated. Illustrations must be provided for by the authors of the papers, or by a special appropriation from the Standing Committee. Immediately on publication of the volume, a copy shall be forwarded to every member and fellow of the Association who shall have paid the assessment for the meeting to which it relates, and it shall also be offered for sale by the Permanent Secretary at such price as may be determined by the Standing Committee. The Standing Committee shall also designate the institutions to which copies shall be distributed.

Local Committee.

Art. 31. The Local Committee shall consist of persons interested in the objects of the Association and residing at or near the place of the proposed meeting. It is expected that the Local Committee, assisted by the officers of the Association, will make all essential arrangements for the meeting, and issue a circular giving necessary particulars, at least one month before the meeting.

Library of the Association.

Art. 32. All books and pamphlets received by the Association shall be in the charge of the Permanent Secretary, who shall have a list of the same printed and shall furnish a copy to any member or fellow on application. Members and fellows who have paid their assessments in full

shall be allowed to call for books and pamphlets, which shall be delivered to them at their expense, on their giving a receipt agreeing to make good any loss or damage and to return the same free of expense to the Secretary at the time specified in the receipt given. All books and pamphlets in circulation must be returned at each meeting, or the value of any not so returned paid to the Permanent Secretary. Not more than ten books, including volumes, parts of volumes, and pamphlets, shall be held at one time by any member or fellow. Any book may be withheld from circulation by order of the Standing Committee.

Admission Fee and Assessments.

Art. 33. The admission fee for members shall be five dollars in addition to the annual assessment. On the election of any member as a fellow an additional fee of two dollars shall be paid.

Art. 34. The annual assessment for members and fellows shall be three dollars.

Art. 35. Any member or fellow who shall pay the sum of fifty dollars to the Association, at any one time, shall become a Life Member and as such shall be exempt from all further assessments, and shall be entitled to the Proceedings of the Association. All money thus received shall be invested as a permanent fund, the income of which shall be used only to assist in original research, unless otherwise directed by unanimous vote of the Standing Committee.

Art. 36. All admission fees and assessments must be paid to the Permanent Secretary, who shall give proper receipts for the same.

Accounts.

Art. 37. The accounts of the Permanent Secretary and of the Treasurer shall be audited annually, by two auditors appointed by the Standing Committee.

Alterations of the Constitution.

Art. 38. No part of this Constitution shall be amended or annulled, without the concurrence of three-fourths of the members and fellows present in general session, after notice given at a general session of a preceding meeting of the Association.

ORDER OF PROCEEDINGS

IN

ORGANIZING A MEETING.

1. The retiring President introduces the President elect, who takes the chair.
2. Formalities of welcome of the Association as may be arranged by the Local Committee.
3. Report of the list of papers on the register and their reference to the Sections.
4. Other reports.
5. Announcements of arrangements by the Local Committee.
6. Elections to complete the Standing Committee.
7. Election of members.
8. Election of fellows.
9. Unenumerated business.
10. Adjournment to meet in Sections.

This order, so far as applicable, to be followed in subsequent General Sessions.

MEMBERS

OF THE

AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.[1]

PATRON.[2]

THOMPSON, MRS. ELIZABETH, Stamford, Conn. (22). (Entitled to annual volume.)

MEMBERS.[3]

Abbot, Miss Elizabeth O., 16 Clark St., Cincinnati, Ohio (20).
Acker, E. O'C., U. S. N., Norristown, Pa. (28).
Agard, Dr. A. H., Oakland, Alameda Co., Cal. (28).
Aikin, Prof. W. E. A., Baltimore, Md. (12).
Albert, Augustus J., Baltimore, Md. (12).
Allen, Edmund T., 419 Olive St., St. Louis, Mo. (27).
Allen, Gerard B., cor. 2nd and Carr streets, St. Louis, Mo. (27).
Allen, J. M., Hartford, Conn. (22).
Allen, Hon. Thomas, St. Louis, Mo. (27).
Ammen, Rear Admiral Daniel, U. S. Navy, Beltsville, Md. (26).
Andrews, James M., jr., Saratoga Springs, N. Y. (28).
Anthony, Prof. Wm. A., Cornell Univ., Ithaca, N. Y. (28).
Appleton, Rev. Edw. W., D.D., Shoemakertown P. O., Montgomery Co., Pa. (28).
Armsby, Henry P., Box 495, New Haven, Conn. (23).

[1] The numbers in parentheses indicate the meeting at which the member was elected. The Constitution requires that the names of all members two or more years in arrears shall be omitted from the list, but their names will be restored on payment of arrearages. Members not in arrears are entitled to the annual volume of Proceedings.

[2] Persons contributing one thousand dollars or more to the Association are classed as Patrons, and are entitled to the privileges of members and to the publications.

[3] Any Member or Fellow may become a Life Member by the payment of fifty dollars. The money derived from Life Memberships is invested as a fund, the income of which is to be used only to aid in original research. Life Members are exempt from the annual assessment, and are entitled to the annual volume. The names of Life Members are printed in small capitals in the regular list of Members and Fellows.

Arthur, J. C., Charles City, Iowa (21).
Atchison, Prof. Thos. A., University of Nashville, Nashville, Tenn. (26).
Atkinson, Jno. B., Earlington, Hopkins Co., Ky. (26).
Atwell, W. H., Care Atwell and Sneed, Nashville, Tenn. (26).

Bachelor, Charles, Electrician, Menlo Park, N. J. (28).
Bailey, E. H. S., Bethlehem, Pa. (25).
Baird, Alexander J., D.D., Nashville, Tenn. (26).
Baker, Prof. T. R., Millersville, Lancaster Co., Pa. (22).
Barnard, Edward E., care R. Poole, Cherry and Union Sts., Nashville, Tenn. (26).
Barnard, Jas. M., 7 Rowes Wharf, Boston, Mass. (18).
Barnard, Wm. S., Ithaca, N. Y. (24).
Barnes, Charles J., Chicago, Ill. (27).
Barnett, Prof. Samuel, jr., Washington, Wilkes Co., Ga. (26).
Barstow, Charles W., St. Louis, Mo. (27).
Bartholomew, Geo. W., 39 Pearl St., Hartford, Conn. (28).
Bartlett, Prof. Edwin J., Dartmouth Coll., Hanover, N. H. (28).
Bartlett, Dr. Homer L., Flat Bush, L. I. (28).
Bassett, George W., M.D., Vandalia, Ill. (20).
Bassnett, Thomas, P. O. Box 936, Jacksonville, Fla. (8).
Bassnett, Mrs. Thomas, P. O. Box 936, Jacksonville, Fla. (24).
Bastian, Dr. David I., Clinton, Worcester Co., Mass. (25).
Bate, Gen. Wm. Brimage, Nashville, Tenn. (26).
Bausch, Edward, Rochester, N. Y. (26).
Beach, Charles M., Merchant, Hartford, Conn. (23).
Beach, J. Watson, Merchant, Hartford, Conn. (23).
Beach, William H., Beloit, Wis. (21).
Beal, Prof. Wm. James, Agricultural College, Lansing, Mich. (24).
Bean, Thos. E., Box 441, Galena, Ill. (28).
Beebe, William, B. A., New Haven, Conn. (28).
Bell, John J., Exeter, N. H. (22).
Bemis, Hon. A. S., President of the Common Council, Buffalo, N. Y. (25).
Benjamin, E. B., 6 Barclay St., New York, N. Y. (19).
Benjamin, Marcus, 6 Barclay St., New York, N. Y. (27).
Bessels, Dr. Emil, Smithsonian Institution, Washington, D. C. (26).
Bessey, Prof. C. E., Agricultural College, Ames, Iowa (21).
Bickmore, Prof. Albert S., Am. Mus. of Nat. Hist., Central Park, New York, N. Y. (17).
Bierstadt, Albert, Brevoort House, New York, N. Y. (28).
Bill, Charles, Springfield, Mass. (17).
Bissell, Wm. S., Pres. Penn. State Agric. Soc'y, Pittsburgh, Pa. (28).
Blackham, Dr. George E., Dunkirk, N. Y. (25).
Blair, Henry W., U.S. Coast Survey, Lexington, Rockbridge Co., Va. (26).
Blatchford, Eliphalet W., 375 North La Salle St., Chicago, Ill. (17).
Boardman, Mrs. Wm. D., 38 Kenilworth St., Roxbury, Mass. (28).

Bowditch, Prof. H. P., Harvard Med. School, Boston, Mass. (28).
Bowen, Edmund S., General Supt. Erie Railway, New York, N Y. (25).
Bowers, Miss Virginia K., Grand Eddy P. O., Perry Co., Mo. (27).
Bowles, Miss Margaretta, P. O. Box 25, Louisville, Ky. (26).
Bowser, Prof. E. A., Rutgers College, New Brunswick, N. J. (28).
Braden, John, D.D.,Pres. Central College, Nashville, Tenn. (26).
Bradley, C. W., 104 North 4th St., St. Louis, Mo. (27).
Breckinridge, S. M., P. O. Box 2794, St. Louis, Mo. (27).
Breneman, A. A., Ithaca, N. Y. (20).
Brewster, Rev. Joseph, New Haven, Conn. (28).
Briggs, Albert D., 7 Fort Block, Springfield, Mass. (13).
Briggs, Charles S., Vanderbilt University, Nashville, Tenn. (26).
Broomall, Hon. John M., Media, Delaware Co., Pa. (23).
Brown, Allan D., Com'dr U. S. N., Aquidneck House, Newport, R. I. (28).
Brown, Mrs. Ashley, 115 Wilkinson St., Dayton, Ohio (25).
Brown, Horace, Counsellor at Law, Salem, Mass. (27).
Brown, Hon. John C., Vice President, Texas and Pacific R. R. Co., Pulaski, Tenn. (26).
Brown, Rev. John Reese, D.D., Nashville, Tenn. (26).
Brühl, Gustav, Cincinnati, Ohio (28).
Bryan, Malachi Thomas, Nashville, Tenn. (26).
Buckhout, W. A., State College, Centre Co., Pa. (20).
Buckingham, Chas. L., U. S. Patent Office, Washington, D. C. (28).
Buist, John Robinson, M.D., Pres. Nashville Board of Health, Nashville, Tenn. (26).
Burke, William, U. S. Patent Office, Washington, D. C. (28).
Bush, Stephen, Waterford, N. Y. (19).
Butters, Alexander, Carlinville P. O., Ill. (27).

Cady, J. C., 111 Broadway, N. Y. (28).
Caldwell, John W., M.D., Stewart College, Clarksville, Tenn. (26).
Calthrop, Rev. S. R., Syracuse, N. Y. (25).
Campbell, A. C., Nashville, Tenn. (26).
Campbell, Mrs. Mary H., Crawfordsville, Ind. (22).
Campbell, Dr. M., Nashville, Tenn. (27).
Canfield, Rev. Eli H., D.D., Arlington, Bennington Co., Vt. (25).
Capen, Miss Bessie T., Northampton, Mass. (23).
Carrington, Col. Henry B., U.S.A., Prof. in Wabash College, Crawfordsville, Ind. (20).
Case, Leonard, Cleveland, Ohio (15).
Case, Col. Theo. S., Ed. Western Review of Science, Kansas City, Mo. (27).
Cassino, S. E., Naturalists' Agency, 299 Washington St., Boston, Mass. (25).
Caswell, John H., 11 West 48th Street, New York, N. Y. (26).
Cattell, William C., President Lafayette College, Easton, Pa. (15).
Chandler, Prof. Chas. Henry, Yellow Springs, Green Co., Ohio (28).

Chapman, F. M., Danforth, Iroquois Co., Ill. (17).
Charbonier, Prof. L. H., University of Georgia, Athens, Ga. (26).
Chase, Prof. F. A., Fisk University, Nashville, Tenn. (26).
Chase, Prof. Pliny E., Haverford College, Haverford, Pa. (18).
Chase, R. Stuart, 16 Merrimack St., Haverhill, Mass. (18).
Chauvenet, Regis, 701 Pine St., St. Louis, Mo. (27).
Chester, Lt. Com'dr Colby M., U. S. N.,Coast Survey Office, Washington, D. C. (28).
Clark, Alvan G., Cambridgeport, Mass. (28).
Clark, F. Y., M.D., Saratoga Springs, N. Y. (28).
Clark, Simeon T., M.D., Lockport, Niagara Co., N. Y. (25).
Clarke, Hon. Enos, St. Louis, Mo. (27).
Cloud, Jno. W., Altoona, Pa. (28).
Coe, Miss Emily M., 33 West 45th St., New York, N. Y. (25).
Coffinberry, W. L., Grand Rapids, Mich. (20).
Colby, C. E., M. E., School of Mines, Columbia College, New York, N. Y. (28).
Collier, M. Dwight, St. Louis, Mo. (27).
Collin, Prof. Alonzo, Cornell College, Mount Vernon, Iowa (21).
Collins, Lieut. Fred'k, U. S. N., Care Navy Department, Washington, D. C. (28).
Colman, Henry, M.D., Swampscott, Mass. (25).
Colton, G. Woolworth, 172 William St., New York, N. Y. (22).
Colvin, Verplanck, Director of Adirondack Survey, Albany, N. Y. (28).
Colyar, John B., Nashville, Tenn. (26).
Comstock, J. Henry, Dep't of Agriculture, Washington, D. C. (28).
Conant, Alban J., St. Louis, Mo. (27).
Cone, James B., 357 Lexington Ave., New York, N. Y. (28).
Cook, Dr. Charles D., 133 Pacific St., Brooklyn, N. Y. (25).
Cooley, Prof. Le Roy C., Vassar College, Poughkeepsie, N. Y. (19).
Copes, Dr. Joseph S., New Orleans, La. (11).
Corson, Mrs. Henrietta H., 137 Washington St., Hartford, Conn. (28).
Couzins, Miss Phœbe W., LL.B., 2647 Washington Ave., St. Louis, Mo. (27).
Coxe, Eckley B., Drifton, Jeddo P. O., Luzerne Co., Pa. (23).
Craig, Dr. Thomas, U. S. Coast Survey Office, Washington, D. C. (28).
Crehore, John D., 458 Prospect St., Cleveland, Ohio (24).
Croly, David G., 162 E. 38th St., New York, N. Y. (28).
Cross, Japheth, Adrian, Mich. (24).
Crow, Wayman, St. Louis, Mo. (27).
Crumbaugh, S. R., Elkton, Ky. (27).
Cummings, J. K., St. Louis Glass Works, St. Louis, Mo. (27).
Cummings, John, Woburn, Mass. (18).
Currier, John McNab, M.D., Castleton, Vt. (28).
Curtis, Greely S., Boston, Mass. (28).
Cusick, C. C., 1st Lieut. 22nd Reg. Infantry, U. S. A., Washington, D.C. (24).
Cutter, John D., P. O. Box 276, New York, N. Y. (23).

Dale, T. Nelson, jr., Paterson, N. J. (27).
Dean, Dr. D. V., St. Louis, Mo. (27).
DeCamp, Dr. William H., Grand Rapids, Mich. (21).
DeForest, Col. J. W., 19 Compton St., New Haven, Conn. (28).
Delano, Joseph C., New Bedford, Mass. (5).
Detviller, H. J., Bethlehem, Pa. (26).
DEVEREUX, J. H., President C.C.C. & I.R.R., Cleveland, Ohio (18).
DeWitt, Marcus Bearden, Nashville, Tenn. (26).
Dinwiddie, Prof. James, Clarksville, Tenn. (26).
Dixwell, Epes S., Cambridge, Mass. (1).
Dodd, C. M., Williamstown, Mass. (19).
Dodd, S. M., St. Louis, Mo. (27).
Doggett, Mrs. Kate N., Chicago, Ill. (17).
Doggett, Wm. E., Chicago, Ill. (17).
Dolbear, A. Emerson, College Hill, Mass. (20).
Donovan, Frank J., 3rd and Pine streets, St. Louis, Mo. (27).
Doolittle, Prof. C. L., South Bethlehem, Pa. (25).
Doughty, John W., Newburgh, N. Y. (19).
Draughon, John A., M.D., Nashville, Tenn. (26).
Drowne, Charles, care William L. Drowne, Esq., Canaan Four Corners, N. Y. (6).
Dudley, Charles B., Altoona, Pa. (23).
Dudley, Wm. L., 19 E 3d St., Covington, Ky. (28).
Duncan, Wm., St. Louis, Mo. (27).
Dunnington, Prof. F. P., University of Virginia, Va. (26).
Duschak, Adolf, 13 Chippewa St., Buffalo, N. Y. (25).
Dyer, Clarence M., Lawrence, Mass. (22).
Dyer, Elisha, 26 Westminster St., Providence, R. I. (9).

Eads, Jas. B., 314 Chestnut Street, St. Louis, Mo. (27).
Eakin, John H., M. A., Nashville, Tenn. (26).
Earll, R. E., Waukegan, Ill. (28).
East, Addison A., M.D., Supt. University Hospital, Nashville, Tenn. (26).
Eaton, Hon. John, U. S. Commiss'r of Education, Washington, D. C. (25).
Eaton, Lucien B., Memphis, Tenn. (26).
Edgar, Col. George M., Principal of Edgar Institute, Paris, Ky. (20).
Edwards, A. Mead, M.D., Berkeley, Alameda Co., Cal. (18).
Edwards, Henry, Wallacks Theatre, New York, N. Y. (28).
Elliott, Arthur H., Peekskill, Westchester Co., N. Y. (23).
Elliott, George B., Nashville, Tenn. (26).
ELWYN, ALFRED L., Philadelphia, Pa. (1).
Emmerton, Mrs. W. H., Salem, Mass. (26).
Endemann, Hermann, Ph. D., 128 Worth St., New York, N. Y. (26).
Enloe, Thos. E., M.D., Nashville, Tenn. (26).
Enos, Alanson T. (27).
Evans, Thos. Wyche, jr., Nashville, Tenn. (26).

Evarts, Herman C., M.D., Frankford, Philadelphia, Pa. (28).
Evers, Dr. Edw., 1737 North Market St., St. Louis, Mo. (28).

Fairchild, H. L., 153 E. 47th St., New York, N. Y. (28).
Farnam, Charles H., New Haven, Conn. (25).
Farnam, Prof. J. E., Georgetown, Ky. (26).
Farnam, William W., New Haven, Conn. (28).
Farquharson, Dr. Robert James, Davenport, Iowa (24).
Ferguson, Maj. Thos. B., Ass't U. S. Fish Commissioner, Washington, D. C. (28).
Fernald, Prof. Charles H., State Agricultural College, Orono, Me. (22).
Fernald, Prof. M. C., State Agricultural College, Orono, Me. (22).
Filley, Giles F., St. Louis, Mo. (27).
Fish, Charles F., Saratoga Springs, N. Y. (28).
Fite, C. C., M.D., Shelbyville, Tenn. (26).
Fleming, Rev. S., Ph. D., Burr Oak, Mich. (27).
Flint, D. B., Watertown, Mass. (25).
Flint, Surgeon James M., U. S. N., 42 Dartmouth St., Boston, Mass. (28).
Flint, Weston, Librarian U. S. Patent Office, Washington, D. C. (28).
Folger, Lt. Comd'r Wm. M., U. S. N., Care Bureau of Ordnance, Navy Dep't, Washington, D. C. (28).
Foreman, Henry L., U. S. Signal Service, Washington, D. C. (23).
Forshey, Col. C. G., New Orleans, La. (21).
Fosgate, Dr. Blanchard, Auburn, N. Y. (7).
Foster, Henry, M.D., Clifton, N. Y. (17).
Foster, Prof. Robert V., Lebanon, Wilson Co., Tenn. (26).
Foster, Wilbur F., Nashville, Tenn. (26).
Frazier, Prof. B. W., The Lehigh University, Bethlehem, Pa. (24).
Frick, John H., Central Wesleyan College, Warrenton, Mo. (27).
Frisby, Prof. Edgar, U. S. N. Observ., Washington, D. C. (28).
Frothingham, Rev. Frederick, Milton, Mass. (11).
Fuller, A. S., Ridgewood, Bergen Co., N. J. (24).
Fulton, Prof. Robert B., University of Mississippi, Oxford, Miss. (21).

Gage, Simon Henry, Ithaca, N. Y. (28).
Gallaudet, Edw. M., Pres. Nat. Deaf Mute College, Washington, D.C. (28).
Gale, Dr. Edward R., Nashville, Tenn. (26).
Garnett, Algernon S., M.D., Hot Springs, Arkansas (23).
Gattinger, August, M.D., Nashville, Tenn. (26).
Gerard, Aristide, New Orleans, La. (26).
Gibbs, Col. Charles N., Sec'y of State, Nashville, Tenn. (26).
Gilmour, Hon. Neil, Sup't of Education, State of N. Y., Balstonspa, N. Y. (28).
Glasgow, Wm., jr., 3016 Glasgow Place, St. Louis, Mo. (27).

Glenny, William H., jr., Buffalo, N. Y. (25).
Gold, Theodore S., West Cornwall, Conn. (4).
Goldschmidt, S. A., Ph. D., 59 & 61 Liberty St., New York, N. Y. (24).
Gooch, Frank A., Cambridge, Mass. (25).
Gordon, Prof. Jos. C , Deaf Mute College, Washington, D. C. (27).
Gould, Sylvester C., Manchester, N. H. (22).
Graef, Edw. L., 40 Court St., Brooklyn, N. Y. (28).
Grant, J. F., M.D., Pulaski, Giles Co., Tenn. (26).
Gratacap, L. P., Ph.B., M. A., American Museum Natural History, Central Park, New York, N. Y. (27).
Green, Caleb, Homer, Cortland Co., N. Y. (28).
Green, J. C., M.D., Buffalo, N. Y. (25).
Greene, Jacob L., Pres. Mut. Life Ins. Co., Hartford, Conn. (23).
Greenough, Malcolm S., 24 West St., Boston, Mass. (28).
Gregory, Prof. J. J. H., Marblehead, Mass. (18).
Gridley, Albert L., Benzonia, Mich. (25).
Grinnell, George Bird, Yale College Museum, New Haven, Conn. (25).
Grossklaus, John F., Navarre, Ohio (24).
Gundlach, Ernst, Rochester, N. Y. (25).
Gunning, William D., Waltham, Mass. (22).

Haggard, W. D., M.D., Nashville, Tenn. (26).
Hague, Arnold, 23 Fifth Avenue, New York, N. Y. (26).
Haines, Reuben, Wayne St., Germantown, Pa. (27).
Hall, Prof. C. W., Univ. of Minnesota, Minneapolis, Minn. (28).
Hambach, Dr. G., 2824 Cass Avenue, St. Louis, Mo. (26).
Hamel, Prof. Thomas E., Laval University, Quebec, Canada (18).
Hammond, Geo. W., Hotel Hamilton, Boston, Mass. (28).
Hanaman, C. E., Troy, N. Y. (19).
Hardy, Prof. A. S., Dartmouth College, Hanover, N. H. (28).
Hare, Prof. R. B., Bells Corners, Ontario, Can. (28).
Harris, W. T., St. Louis, Mo. (27).
Harrison, Edwin, 941 North Second St., St. Louis, Mo. (11).
Hart, Rev. Prof. Samuel, Trinity College, Hartford, Conn. (22).
Harvey, Charles W., Sup't Public Schools, Greensburg, Ind. (20).
Harvey, Dr. Leon F., Buffalo, N. Y. (22).
Hatfield, Marcus P., M.D., Chicago Medical College, Chicago, Ill. (23).
Hawkins, Marion S., 60 High St., Nashville, Tenn. (26).
Hayes, George E., 1125 Main Street, Buffalo, N. Y. (15).
Hayes, Richard, 700 Chestnut St., St. Louis, Mo. (27).
Haynes, Henry W., 239 Beacon St., Boston, Mass. (28).
Hazen, E. H., M.D., Davenport, Iowa (25).
Hedge, Fred. H., jr., Public Library, Lawrence, Mass. (28).
Henderson, John G., Winchester, Ill. (25).
Hensel, Martin, Columbus, Ohio (25).
Herdman, W. J., Ann Arbor, Mich. (24).

Hicks, Geo. W., Nashville, Tenn. (27).
Hicks, John D., Old Westbury, Queen's Co., L. I. (23).
Higginson, John A., 260 Clarendon St., Boston, Mass. (26).
Hilder, F. F., 604 North 4th St., St. Louis, Mo. (26).
Hinds, Prof. J. I. D., Cumberland University, Lebanon, Tenn. (26).
Hitchcock, Henry, 404 Market St., St. Louis, Mo. (27).
Hobbs, A. C., Bridgeport, Conn. (28).
Hoffman, Dr. Fred., 797 Sixth Ave., New York, N. Y. (28).
Hogg, Prof. Alexander, College Station, Brazos Co., Texas (26).
Holbrook, F. N., E. M., School of Mines, Columbia Coll., New York, N. Y. (26).
Holbrooke, Prof. Geo. O., Trinity College, Hartford, Conn. (27).
Holley, George W., Niagara Falls, N. Y. (19).
Holmes, John C., Room No. 41 Moffat Block, Detroit, Mich. (24).
Holstein, Geo. Wolf, Belvidere, N. J. (28).
Homes, Henry A., Librarian State Library, Albany, N. Y. (11).
Hopkirk, Prof. W. H., 505 Summer St., Burlington, Iowa (24).
Hornaday, William T., 19 Rowley St., Rochester, N. Y. (25).
Horr, Asa, M.D., Dubuque, Iowa (21).
Horton, Rev. Sanford J., D.D., Cheshire, Conn. (28).
Houston, George M., Harrisonville, Mo. (26).
Howe, Andrew J., M.D., Cincinnati, Ohio (28).
Howell, Edwin E., Rochester, N. Y. (25).
Hoyte, James W., D.D., Nashville, Tenn. (26).
Hubbard, George W., M.D., Nashville, Tenn. (26).
Hubbard, Mrs. Sara A., 31 Thirty-third St., Chicago, Ill. (17).
Humphrey, D., M.D., Lawrence, Mass. (18).
Humphreys, A. W., Box 1384, New York, N. Y. (20).
Hunt, Miss Sarah E., Salem, Mass. (20).
Hunting, Rev. S. S., Davenport Academy Natural Sciences, Davenport, Iowa (26).
Huntington, Prof. Chester, Clinton, Oneida Co., N. Y. (26).
Hyde, Prof. E. W., Walnut Hills, Cincinnati, Ohio (25).

Ingram, Mrs. H. K., Nashville, Tenn. (26).
Irish, Thomas M., 58 Prairie St., Dubuque, Iowa (21).
Isawa, Shuje, care G. Attwood, 53 State St., Boston, Mass. (26).

Jackson, Thomas J. (26).
James, Frederick H., M.D., Lancaster, N. Y. (25).
Jewell, Pliny, Mineralogical Amateur, Hartford, Conn. (23).
Jewell, Theo. F., Lt. Comdr. U.S.N., care Riggs & Co., Washington, D. C. (25).
Jillson, Dr. B. C., Pittsburgh, Pa. (14).
Johnson, Prof. Hosmer A., Academy of Sciences, Chicago, Ill. (22).

Johnston, J. Frank, Bethlehem, Pa. (25).
Jones, Hon. H. M., St. Louis, Mo. (27).
Jones, Col. James H., U. S. Marines, Boston, Mass. (28).
Jones, Prof. Oliver V., McKendree College, Lebanon, Ill. (27).
Jones, Prof. Richard W., University of Mississippi, Oxford, Miss. (25).
Jones, Dr. Wm. L., Ed. Southern Cultivator, Athens, Ga. (26).
Jones, Wm. P., M.D., Pres. Nashville Med. College, Nashville, Tenn. (26).
Justus, Irving J., Stanfordville, Duchess Co., N. Y. (28).

Kedzie, Prof. W. K., Oberlin College, Oberlin, Ohio. (25).
Kellogg, John H., M.D., Battle Creek, Mich. (24).
Kent, William, Pittsburgh, Pa. (26).
Killebrew, J. B., Commissioner of Agriculture, Nashville, Tenn. (26).
Kimball, Geo. G., Washington, D. C. (28).
Kinder, Miss Sarah, 27 Lockerbie St., Indianapolis, Ind. (20).
King, Clarence, U. S. Geol. Expl. of the 40th Parallel, 23 Fifth Ave., New York, N. Y. (26).
King, Ephraim L., M.D., Box 251, Ashtabula, Ohio (24).
King, Miss Harriet, Salem, Mass. (28).
King, Mrs. Mary B. A., 21 Madison St., Rochester, N. Y. (15).
Kinner, Dr. Hugo, 1517 South Seventh St., St. Louis, Mo. (21).
Kinnicutt, Leonard P., Worcester, Mass. (28).
Kirkpatrick, James A., 19 South Fifth St., Philadelphia, Pa. (7).
Kite, Thomas, 75 West 4th St., Cincinnati, Ohio (5).
Knapp, Frederick N., Plymouth, Mass. (19).
Kneeland, Dr. Samuel, 61 Court St., Room 5, Boston, Mass. (20).
Kocsis, Alexander, Tullahoma, Tenn. (26).

Lakes, Prof. Arthur, State School of Mines, Golden City, Col. (26).
Lamborn, Robert H., 208 South 4th St., Philadelphia, Pa. (28).
Larkin, Edgar L., New Windsor, Mercer Co., Ill. (28).
Larkin, Frederick, M. D., Randolph, N. Y. (28).
Laudy, Louis H., School of Mines, Columbia College, New York, N. Y. (28).
Lawrence, Hon. Edw., Pres't Bunker Hill National Bank, Charlestown, Mass. (18).
Lea, John McCormick, Nashville, Tenn. (26).
Learned, Rev. J. C., St. Louis, Mo. (27).
Ledoux, Albert R., Ph. D., State Chemist, Chapel Hill, N. C. (26).
Leete, James M., M.D., 2912 Washington Avenue, St. Louis, Mo. (27).
Leland, Eugene R., P. O. Box 2364, New York, N. Y. (25).
Lemoine, Dr. E. S., St. Louis, Mo. (27).
Lemp, Wm. J., cor. Cherokee and 2nd Carondelet Ave., St. Louis, Mo. (27).
Lesley, Joseph, 233 South Fourth St., Philadelphia, Pa. (8).
Letchworth, Josiah, Buffalo, N. Y. (25).

Letterman, G. W., Allenton, Mo. (27).
Lewis, Elias, jr., 111 St. Mark's Ave., Brooklyn, N. Y. (23).
Lewis, Henry C., E. Washington Lane, Germantown, Pa. (26).
Linderman, Dr. G. B., Bethlehem, Pa. (28).
LILLY, GEN. WM., Mauch Chunk, Carbon Co., Pa. (28).
Lindsley, Adrian Van S., Sec'y Univ. of Nashville, Nashville, Tenn. (26).
Lindsley, Adrian Van S., jr., Nashville, Tenn. (26).
Lindsley, Miss Louise, Nashville, Tenn. (26).
Lindsley, Miss Mary McG., Nashville, Tenn. (26).
Lindsley, Van Sinderen, M.D., Nashville, Tenn. (26).
Lippman, Morris J., care Graff, Bennett & Co., St. Louis, Mo. (27).
Loomis, Leverett M., Chester, S. C. (28).
Losey, L. L., Nashville, Tenn. (26).
Love, Edward G., School of Mines, Columbia College, New York, N. Y. (24).
Lovewell, Prof. Joseph T., Washburn College, Topeka, Kansas (25).
Lowry, Prof. Thos. J., Columbia P. O., Boone Co., Mo. (26).
Lull, Commander Edward P., U. S. N., Washington, D. C. (28).
Lyford, Prof. Moses, Waterville, Me. (22).
Lyle, Lieut. David Alexander, Ordnance Department, U. S. A., National Armory, Springfield, Mass. (28).
LYMAN, BENJ. SMITH, Tokio, Japan (15).
Lyons, T. A., Lieut. U. S. N., U. S. Flagship, Trenton, European Station, care B. F. Stevens, Esq., No. 4 Trafalgar Square, Charing Cross, London, England (28).

MacArthur, Charles L., Troy, N. Y. (19).
Mack, William, M.D., Salem, Mass. (21).
Mackintosh, James B., School of Mines, Columbia Coll., New York, N. Y. (27).
Macloskie, Prof. George, College of New Jersey, Princeton, N. J. (25).
Macy, Arthur, C. E., 26 Cedar Street, New York, N. Y. (26).
Maghee, J. Holme, 16 East 54th St., New York, N. Y. (26).
Mallery, Brevet Lieut. Col. Garrick, U. S. Army, P. O. Box 585, Washington, D. C. (26).
Mann, Miss M. P., Troy Seminary, Troy, N. Y. (28).
Marcy, Henry O., M. D., 690 Main St. Cambridge, Mass. (28).
Marsden, Samuel, 907 Clay Ave., St. Louis, Mo. (27).
Marshall, William I., Fitchburg, Mass. (27).
Martin, Prof. B. N., 236 W. 4th St., New York, N. Y. (23).
Martin, Prof. Daniel S., Rutger's Female College, New York, N. Y. (23).
Martin, Prof. H. Newell, Johns Hopkins Univ., Baltimore, Md. (27).
Martindale, Isaac C., Camden, N. J. (26).
Marvin, Hon. Wm.. Skaneateles, N. Y. (28).
Mathews, Robert, 28 Spring St., Rochester, N. Y. (25).
Matlack, Charles, Germantown, Pa. (27).

Matthews, Commander E. O., U. S. N., Inspector of Ordnance, Navy Yard, New York, N. Y. (28).
Maude, John B., St. Louis, Mo. (27).
May, Calvin S., M. D., Superintendent Insane Asylum, Danvers, Mass (28).
McClung, Calvin M., Knoxville, Tenn. (26).
McCutchen, Aug. R., La Fayette, Ga. (25).
McGee, W. J., Farley, Dubuque Co., Iowa (27).
McNair, Lt. Com. Antoine R., U. S. N., P. O. Box 1071, Saratoga Springs, N. Y. (28).
McNair, F. V., Commander U. S. N. Naval Academy, Annapolis, Md. (28).
McNeal, Albert T., Bolivar, Tenn. (26).
McWhorter, Tyler, Aledo, Ill. (20).
Meier, Theodore G., St. Louis, Mo. (27).
Mellier, A. A., St. Louis, Mo. (27).
Metcalf, Caleb B., Highland Military Academy, Worcester, Mass. (20).
Miller, John A., Box 110, Paducah, Ky. (22).
Miller, S. A., Cincinnati, Ohio (26).
Miniñe, William, 5 North Charles St., Baltimore, Md. (12).
Minot, Charles Sedgwick, Roslindale P. O., Boston, Mass. (28).
Moffatt, George T., M. D , D. M. D., 196 Boylston St., Boston, Mass. (25).
Molíner, Adolfo, Havana, Cuba (28).
Mooar, Daniel, Keokuk, Iowa (27).
Moody, Mrs. Mary B., 187 N. Pearl St., Buffalo, N. Y. (25).
Moore, Edward M., M.D., Rochester, N. Y. (25).
Morehouse, Geo. W., Wayland, Steuben Co., N. Y. (24).
Morgan, Horace H., St. Louis, Mo. (27).
Morgan, Wm. F., 1 East 40th St., New York, N. Y. (27).
Morison, Dr. N. H., Provost of Peabody Institute, Baltimore, Md. (17).
Morris, John B., Nashville, Tenn. (26).
Moser, Lieut. Jeff. F., U. S. N., Slatington, Pa. (28).
Moses, Prof. Thos. F., Urbana University, Urbana, Ohio (25).
Mott, Dr. H. A., jr., 98 Wall St., New York, N. Y. (27).
Moulton, Jno. B., 2614 North 9th St., St. Louis, Mo. (27).
Muir, John, 920 Valencia St., San Francisco, Cal. (22).
Munroe, Prof. Henry S., School of Mines, Columbia College, New York, N.Y. (26).
Murdock, Lieut. J. B., U. S. N., care Rev. J. N. Murdock, Box 21, Boston, Mass. (28).
Murtfeldt, Miss Mary E., Kirkwood, Mo. (27).

Nelson, Anson, Recording Sec'y Tenn. Hist. Society, Nashville, Tenn. (26).
Newland, John, Saratoga Springs, N. Y. (28).
Newton, Rev. John, Mary Esther, West Fla. (7).
Nichols, E. L., Ph. D., Johns Hopkins Univ., Baltimore, Md. (28).
Nichols, S. H., 415 South 15th St., Philadelphia, Pa. (28).
Nicholson, Prof. Hunter, Knoxville, Tenn. (26).

Norwood, Charles J., Ass't Kentucky Geological Survey, Russellville, Ky. (26).
Nowlin, John B. W., M.D., Nashville, Tenn. (26).

Oehler, Arthur, Highland, Madison Co., Ill. (27).
Olmsted, Fred. Law, 209 W. 46th St., New York (22).
Olshausen, Ernest P., No. 10 South 4th St., St. Louis, Mo. (27).
Orm, John, Paducah, McCracken Co., Ky. (27).
Osborne, Mrs. Ada M., Waterville, Oneida Co., N. Y. (19).
Osborne, Amos O., Waterville, Oneida Co., N. Y. (19).
Osler, Prof. William, McGill College, Montreal, Canada (28).
Overstolz, Hon. Henry, Mayor of St. Louis, St. Louis, Mo. (27).

Paine, Charles, Gen. Supt. Lake Shore & Southern Railway Co., Cleveland, Ohio (22).
Palmer, Miss Alice W., Bellevue St., Boston Highlands, Mass. (27).
Palmer, Rev. Benj. M., Box 1628, New Orleans, La. (21).
Palmer, Dr. Edward, care Peabody Museum, Cambridge, Mass. (22).
Parmele, Geo. L., M.D., D. M. D., 25 Pratt St., Hartford, Conn. (27).
Parvin, Theodore S., Iowa City, Iowa (7).
Patrick, Dr. J. J. R., Belleville, St. Clair Co., Ill. (27).
Patterson, James S., Nashville, Tenn. (26).
Patterson, John P., Supt. Instruction, Washington C. H., Ohio (25).
Paul, Caroline A., M.D., Vineland, Cumberland Co., N. J. (23).
Payn, Charles H., M. D., Saratoga Springs, N. Y. (28).
Peabody, Prof. F. Downing, Hopkinsville, Ky. (26).
Peck, W. A., C. E., Idaho Springs, Clear Creek Co., Col. (19).
Peet, Rev. Stephen D., Clinton, Wis. (24).
Peirce, Prof. Benjamin, Cambridge, Mass. (1).
Peirce, Prof. James M., Cambridge, Mass. (28).
Percival, Rev. Chester S., Marshalltown, Iowa (21).
Perkins, Prof. George H., Burlington, Vt. (17).
Phelps, Mrs. Almira Lincoln, Baltimore, Md. (13).
Phelps, Gen. Charles E., Baltimore, Md. (13).
Philbrick, Prof. Philetus H., Iowa City, Iowa (23).
Phillips, W. B., Ph. B., Chapel Hill, N. C. (27).
Phythian, Commander Robert L., U. S. N., Frankfort, Ky. (28).
Pickett, Dr. Thos. E., Maysville, Mason Co., Ky. (25).
Pigue, Edward H., Nashville, Tenn. (26).
Pilling, James C., Box 585, Washington, D. C. (28).
Pillsbury, John H., 24 Bliss St., Springfield, Mass. (23).
Pinkerton, T. H., M.D., Oakland, Alameda Co., Cal. (27).
Pitt, Prof. William H., Buffalo, N. Y. (25).
Platt, Franklin, Ass't Geologist, 2nd Geol. Survey of Pa., 615 Walnut St., Philadelphia, Pa. (27).
Plunket, James D., M.D., Pres. State Bd. of Health, Nashville, Tenn. (26).

Porteous, John, 26 Prince Arthur St., Montreal, Canada (22).
Porter, Mrs. Felicia G., Nashville, Tenn. (27).
Porter, Hon. F. T., Governor of Tennessee, Nashville, Tenn. (26).
Potter, Prof. William B., Washington University, St. Louis, Mo. (25).
Preston, Prof. W. C., Laboratory, Iowa State Univ., Iowa City, Iowa (21).
Prichitt, Samuel, Nashville, Tenn. (26).
Prince, Gen. Henry, U.S.A., Headquarters of the Army, San Francisco, Cal. (22).
Procter, John R., Ass't Ky. Geol. Survey, Frankfort, Ky. (26).
Prosser, Col. Wm. F., Nashville, Tenn. (26).
Pulsifer, Sidney, 405 South 42nd St., Philadelphia, Pa. (21).
Putnam, Chas. P., M. D., 63 Marlborough St., Boston, Mass. (28).
Putnam, James J., M. D., 63 Marlborough St., Boston, Mass. (28).
Putnam, J. Duncan, Cor. Sec. Davenport Acad. of Nat. Sciences, Davenport, Iowa (27).

Rand, C. F., M.D., Batavia, N. Y. (27).
Reed, Edmund B., London, Ontario, Canada (27).
Reed, S. A., M. E., 6 East 53rd St., New York, N. Y. (28).
Rice, Rev. Wm., D. D., Springfield, Mass. (28).
Richardson, F. C. A., Nat. Stock Yards, E. St. Louis, Mo. (20).
Ricketts, Pierre de Peyster, Ph.D., School of Mines, Columbia College, New York, N. Y. (26).
Riggs, Geo. W., jr., Washington University, St. Louis, Mo. (26).
Rivers, E. R., Agricultural and Mechanical College, Auburn, Ala. (26).
Robertson, Col. Robert S., Fort Wayne, Ind. (20).
Robertson, Thomas D., Rockford, Ill. (10).
Robinson, Henry C., Lawyer, Hartford, Conn. (23).
Robinson, Prof. Otis Hall, Rochester, N. Y. (23).
Rockwell, Chas. H., P. O. Box 293, Tarrytown, N. Y. (28).
Rogers, A. J., Milwaukee, Wis. (25).
Root, Prof. Elihu, Amherst College, Amherst, Mass. (25).
Rosenspitz, Rev. Alexander, Quincy, Ill. (26).
Rumsey, Bronson C., 58 and 60 Exchange St., Buffalo, N. Y. (15).
Rupp, Wm., 961 3d Ave., New York, N. Y. (27).
Russell, I. C., School of Mines, New York, N. Y. (25).
Russell, W. H. H., S. W. cor. Fifth and Olive streets, St. Louis, Mo. (24).
Rust, Horatio N., cor. Rush and Kinsie streets, Chicago, Ill. (26).

Safford, Charles W., Rutland, Vt. (26).
Sage, John H., Portland, Conn. (23).
Sampson, Com'd W. T., U.S.N., Naval Academy, Annapolis, Md. (25).
Sander, Dr. Enno, St. Louis, Mo. (27).
Sanders, Benjamin D., Wellsburg, Brooke County, W. Va. (19).
Sayre, Robert H., Bethlehem, Pa. (28).
Scammon, J. Young, Chicago, Ill. (17).

Schæffer, E. M., M. D., 1115 F St., N. W., Washington, D. C. (28).
Schaffranck, Dr. A., Box 424, Wheeling, W. Va. (27).
Schanck, Prof. J. Stillwell, Princeton, New Jersey (4).
Schley, Wm., 601 Fifth Ave., New York (28).
Schley, William S., Macon, Ga. (26).
Schmid, Dr. H. Ernest, White Plains, N. Y. (25).
Scobey, James E., Pres. Murfreesboro Fem. Inst., Murfreesboro, Tenn. (26).
Seagrave, Frank E., Providence, R. I. (28).
Seymour, Prof. William P., 105 Third St., Troy, N. Y. (19).
Shackelford, Mrs. Elizabeth P., Saratoga Springs, N. Y. (28).
Sharp, Prof. Solomon Z., Ashland, Ohio (26).
Shaub, Julius W., Washington Univ., St. Louis, Mo. (27).
Shaw, Henry, St. Louis, Mo. (27).
Sheafer, A. W., Pottsville, Pa. (28).
Sheafer, Walter S., Pottsville, Pa. (25).
Shepard, William A., Saratoga Springs, N. Y. (28).
Shepherd, F. A., 21 North Vine Street, Nashville, Tenn. (26).
Short, Sidney H., Ohio State Univ., Columbus, Ohio (28).
Shumard, Mrs. Elizabeth M., Columbia, Boone Co., Mo. (26).
Sigsbee, Lt. Comd'r Chas. D., U. S. N. Navy Department, Washington, D. C. (28).
Simonds, Frederic W., Prof. of Nat. History, Univ. of N. Carolina, Chapel Hill, N. C. (25).
Simpson, E., Commander U. S. N., New London, Conn. (28).
Skinner, Joseph J., P. O. Box, 729, New Haven, Conn. (23).
Smiley, Charles W., Smithsonian Institution, Washington, D. C. (28).
Smith, Carlos G., Pres. University of Alabama, Tuscaloosa, Ala. (26).
Smith, Prof. Charles A., Washington Univ., St. Louis, Mo. (27).
Smith, Mrs. Erminnie A., 203 Pacific Ave., Jersey City, N. J. (25).
Smith, Prof. F. H., University of Virginia, Charlottesville, Va. (26).
Smith, Henry L., 149 Broadway, New York, N. Y. (26).
Smith, Mrs. Henry L., 149 Broadway, New York, N. Y. (26).
Smith, Henry T., Buffalo, N. Y. (25).
Smith, Herbert W., Academy of Sciences, P. O. Box 2621, St. Paul, Minn. (26).
Smith, J. W., M.D., Charles City, Iowa (21).
Smith, Quintius C., M. D., P. O. Box 6, Austin, Texas (26).
Smith, Robert D., Pres. Columbia Athenæum, Columbia, Tenn. (26).
Smith, Mrs. Sarah J. (26).
Smith, William Austin, M. D., Columbia, Tenn. (26).
Smith, Prof. William H., Nashville, Tenn. (26).
Smyth, Prof. Jas. D., Burlington, Iowa (28).
Snively, Prof. John H., Nashville, Tenn. (26).
Snyder, Prof. Monroe B., High School Observatory, Philadelphia, Pa. (24).
Soper, A. W., St. Louis, Mo. (27).
Southworth, Mase S., Ph.D., Williamstown, Mass. (25).
Speck, Hon. Charles, St. Louis, Mo. (27).
Spencer, Prof. J. W., Kings College, Windsor, N. S. (28).

Spinzig, Charles, 1300 S. 5th St., St. Louis, Mo. (27).
Springer, Alfred, Cincinnati, Ohio (24).
Stæbner, Fred W., No. 2 College Ave., Rochester, N. Y. (28).
Stearns, Eben S., Chancellor Univ. of Nashville, Nashville, Tenn. (26).
Stearns, Silas, Assistant U. S. Fish Commission, Pensacola, Fla. (28).
Stearns, Winfrid Alden, Fishkill on the Hudson, N. Y. (23).
Sternberg, George M., Surgeon U.S.A., Care Surgeon General, U.S.A., Washington, D. C. (24).
Stevens, Geo. T., M. D., Albany, N. Y. (28).
Stevens, R. P., Jamaica, N. Y. (18).
Stevenson, W. G., M. D., Poughkeepsie, N. Y. (28).
Stewart, Prof. Elliott W., Lake View, Erie Co., N. Y. (25).
Stillman, W. O., M. D., Saratoga Springs, N. Y. (28).
Stimpson, Thomas M., Peabody, Mass. (18).
St. John, Jas. A., St. Louis, Mo. (27).
St. John, Prof. Jos. S., Albany, N. Y. (28).
Stone, Miss Mary H., Salem, Mass. (25).
Storer, Dr. D. H., Boston, Mass. (1).
Storer, Prof. Frank H., Jamaica Plain, Mass. (13).
Stowell, John, 48 Main Street, Charlestown, Mass. (21).
Stowell, Prof. T. B., Cortland, N. Y. (28).
Straight, Prof. H. H., Oswego, N. Y. (25).
Sullivan, J. A., U. S. Coast Survey Office, Washington, D. C. (27).
Summers, Thos. O., M. D., Vanderbilt Univ., Nashville, Tenn. (22).
Sutton, Dr. George, Aurora, Dearborn Co., Ind. (20).
Swasey, Oscar F., M.D., Beverly, Mass. (17).

Talbot, Henry, Waterloo, Monroe Co., Ill. (27).
Tatum, Jos. T., 221 Chestnut St., St. Louis, Mo. (27).
Taylor, Wm. Curtis, 914 Chestnut St., Philadelphia, Pa. (24).
Terry, James, American Museum Natural History, Central Park (77th St. and 8th Ave.), New York, N. Y. (28).
Theobald, Albert G. R., Forest Dept., Anamalai, Coimbatore District, India (27).
Thompson, Harvey M., Clarendon House, Chicago, Ill. (17).
Thomson, Prof. A., Ames, Iowa (21).
Thruston, Gates P., Cor. Sec. Tenn. Hist. Society, Nashville, Tenn. (26).
Thurber, Miss Elizabeth, Plymouth, Mass. (22).
Tiffany, Asa S., 901 West 5th St., Davenport, Scott Co., Iowa (27).
Tittmann, Otto H., U. S. Coast Survey, Washington, D. C. (24).
Todd, Albert, St. Louis, Mo. (27).
Todd, D. P., Nautical Almanac Office, Washington, D. C. (27).
Todd, Prof. James E., Tabor, Fremont Co., Iowa (22).
Tomlinson, Dr. J. M., 28 East Ohio St., Indianapolis, Ind. (20).
Toney, Rev. Thomas, Nashville, Tenn. (26).
Toombs, Robert, M. D., Washington, Ga. (26).
Townsend, Franklin, Adj. Gen. State of N. Y., Albany, N. Y. (4).

Townshend, Prof. N. S., Columbus, Ohio (17).
Tracy, Sam'l M., Columbia, Boone Co., Mo. (27).
Treat, Hon Sam'l, St. Louis, Mo. (27).
Trembley, J. B., M.D., Oakland, Alameda Co., Cal. (17).
Triplett, Wm. H., M. D., 1019 F St., N. W., Washington, D. C. (28).
Trowbridge, Mrs. L. H., 211 Jefferson Ave., Detroit, Mich. (21).
Trowbridge, S. H. Glasgow, Mo. (27).
True, Fred W., Ass't U. S. Fish Commission, Washington, D. C. (28).
Tutt, Thos. E., Third Nat. Bank, St. Louis, Mo. (27).
Tutwiler, Henry, Greene Springs, Ala. (26).

Underwood, Rev. W., D D., M. D., LL. D., Fredericksburg, Washington Co., Ind. (26).
Upham, Dr. J. Baxter, 31 Chestnut St., Boston, Mass. (14).
Upham, Warren, Nashua, N H. (25).
Upton, Francis R., Electrician, Menlo Park, N. J. (28).

Vail, Prof. Hugh D., 1927 Mt. Vernon St., Philadelphia, Pa. (18).
Van Brunt, C., Poughkeepsie, N. Y. (28).
Van Dyck, Prof. Francis Cuyler, New Brunswick, N. J. (28).
Vaughn, Prof. Wm. J., Univ. of Alabama, Tuscaloosa, Ala. (26).
Very, Lt. S. W., U. S. Naval Academy, Annapolis, Md. (28).
Vieth, William, Cor. 8th and Freeman Sts., Cincinnati, O. (28).

Wakeman, Thaddeus B., 93 Nassau St., New York, N. Y (25).
Walcott, Charles D., U. S. Geol. Survey, Washington, D. C. (25).
Waldo, Leonard, S. D., Harvard Coll. Observ., Cambridge, Mass. (28).
Walker, Dr. G. S., St. Louis, Mo. (27).
Walker, George C., 13 Chamber of Commerce, Chicago, Ill. (17).
Walker, N. B., 19 and 21 Cliff St., New York, N. Y. (20)
Wall, John L., 338 Sixth Avenue, New York, N. Y. (21).
Walworth, Rev. Clarence, Albany, N. Y. (28).
Walworth, Mrs. Ellen Hardin, Saratoga Springs, N. Y. (28).
Walmsley, W. H., 1016 Chestnut St., Philadelphia, Pa. (28).
Wallace, Wm., Ansonia, Conn. (28).
Ward, W. E., D.D., President Ward's Seminary for Young Ladies, Nashville, Tenn. (26).
Warder, Robert B., Prof. of Chem. and Physics, Haverford College P. O., Pa. (19).
Wardwell, George J., Rutland, Vt. (20).
Warner, Mrs. J. D., 199 Baltic St., Brooklyn, N. Y. (21).
Warren, G. Washington, 54 Devonshire St., Room 1, Boston, Mass. (18).
Warring, Charles B., Poughkeepsie, N. Y. (25).
Watkins, Samuel, President Board of Education, Nashville, Tenn. (26).
Wead, Prof. Charles K., Univ. of Michigan, Ann Arbor, Mich. (23).

Weakley, Richard W., Supt. Public Schools, Nashville, Tenn. (26).
Webb, Benjamin, jr., Salem, Mass. (18).
Webster, Prof. H. E., Union College, Schenectady, N. Y. (23).
Weld, Mrs. Amy T., 119 East 23 St., New York, N. Y. (28).
Wells, George A., Troy, N. Y. (19).
Wells, Samuel, 31 Pemberton Square, Boston, Mass. (24).
Wheeler, Prof. C. G., University of Chicago, Chicago, Ill. (18).
Wheeler, Orlando B., Ass't U. S. Lake Survey, Detroit, Mich. (24).
Wheeler, T. B., M. D., 714 Craig St., Montreal, Canada (11).
White, Prof. I. C., University of W. Va., Morgantown, W. Va. (25).
White, LeRoy S., Box 157, Waterbury, Conn. (23).
White, Samuel S., Chestnut St., cor. Twelfth, Philadelphia, Pa. (23).
White, Thomas W., Hernando, De Soto Co., Miss. (28).
White, Z. L., Washington, D. C. (26).
Whiting, Lewis E., M. D., Saratoga Springs, N. Y. (28).
Whitman, Chas. O. (27).
Whitney, Mary W., Waltham, Mass. (19).
Whitworth, John L., Nashville, Tenn. (26).
Wilbour, Mrs. Charlotte B., 151 East 51st St., New York, N. Y (28).
Wilder, Gen. John T., Chattanooga, Tenn. (26).
Wilkin, Daniel F., Nashville, Tenn. (26).
Williams, Charles H., Buffalo, N. Y. (25).
Williams, Edward H., jr., Danville, Pa. (25).
Williams, Frank, Buffalo, N. Y. (25).
Williams, H. S., Cornell University, Ithaca, N. Y. (18).
Williams, P. O., M.D., Watertown, Jefferson Co., N. Y. (24).
Williams, Rev. R. R., Canajoharie, Montgomery Co., N. Y. (28).
Williams, Willoughby, Nashville, Tenn. (26).
Williamson, Lieut. Col. R. S., U. S. Engineers, Light House Engineer, San Francisco, Cal. (12).
Willoughby, Hugh L., Saratoga Springs, N. Y. (28).
Wills, A. W., corner Union and Cherry streets, Nashville, Tenn. (26).
Wilmot, Thos. J., Direct U. S. Cable Co., Rye, N. H. (27).
Wilson, Prof. Hiram A., Saratoga Springs, N. Y. (28).
Wilson, M. C., Russellville, Ala. (26).
Worthen, F. W. D., Hanover, N. H. (28).
Woodward, J. J., M. D., Army Medical Museum, Washington, D. C. (28).
Wright, Prof. Albert A., Oberlin College, Oberlin, Ohio (24).

Yeatman, Prof. Joseph W., Nashville, Tenn. (26).
Youmans, Wm. Jay, M. D., Popular Science Monthly, 549 Broadway, New York, N. Y. (28).

[677 MEMBERS.]

NOTE.—The omission of an address in the foregoing list, indicates that letters directed to that last printed were returned as uncalled for. Information of the present address of the members so indicate is requested by the PERMANENT SECRETARY.

FELLOWS.[1]

Abbe, Prof. Cleveland, Washington, D. C. (16). 1874.
Agassiz, Alex., Curator Mus. Comp. Zool., Cambridge, Mass. (18). 1875.
Alexander, John S., 1935 Arch St., Philadelphia, Pa. (20). 1874.
Allen, Zachariah, Providence, R. I. (1). 1874.
Alvord, Benj., Pay'r Gen., U. S. Army, Washington, D. C. (17). 1874.
Appleton, Prof. John H., Brown Univ., Providence, R. I. (22). 1874.
Austen, Peter T., Ph. D., Rutgers College, Lock Box No. 2, New Brunswick, N. J. (26). 1879.
Austin, E. P., 46 E. Newton St., Boston, Mass. (18). 1874.

Bailey, Prof. Loring W., University of Fredericton, N. B. (18). 1875.
Bailey, W. W., Instructor of Botany, Brown University, Providence, R. I. (18). 1874.
Baird, Prof. S. F., Sec'y Smith. Inst., Washington, D. C. (1). 1875.
Bandelier, Ad. F., Highland, Ill. (25). 1879.
Barker, Prof. G. F., Univ. of Penn., Philadelphia, Pa. (13). 1875.
Barnard, F. A. P., President Columbia College, New York, N. Y. (7). 1874.
Barnard, Gen. J. G., U. S. Army, Army Building, New York, N. Y. (14). 1875.
Bassett, Homer F., Waterbury, Conn. (23). 1874.
Batchelder, Dr. J. H., Salem, Mass. (18). 1874.
Batchelder, John M., 3 Divinity Avenue, Cambridge, Mass. (8). 1875.
Bell, Prof. Alex. Graham, Boston University, Boston, Mass. (26). 1879.
Bell, Samuel N., Manchester, N. H. (7). 1874.
Bethune, Rev. C. J. S., Trinity Coll. School, Pt. Hope, Canada (18). 1875.
Blackie, Geo. S., M. D., Nashville, Tenn. (26). 1877.
Blake, Clarence J., M. D., Hotel Berkeley, Boston, Mass. (24). 1877.
Blake, Eli W., New Haven, Conn. (1). 1874.
Blake, Prof. Eli W., jr., Providence, R. I. (15). 1874.
Blake, Francis, jr., U. S. Coast Survey, Newton Lower Falls, Mass. (23). 1874.
Bolton, Dr. H. Carrington, Trinity Coll., Hartford, Conn. (17). 1875.
Boss, Prof. Lewis, Director Dudley Observ., Albany, N. Y. (26). 1878.
Bouvé, Thos. T., Pres't Boston Soc. Nat. Hist., Boston, Mass. (1). 1875.
Bowditch, Henry I., M.D., 113 Boylston St., Boston, Mass. (2). 1875.
Brackett, Prof. C. F., College of New Jersey, Princeton, N. J. (19). 1875.
Brewer, Prof. Wm. H., Box 55, New Haven, Conn. (20). 1875.
Broadhead, Garland Carr, Pleasant Hill, Cass Co., Mo. (27). 1879.
Brocklesby, Prof. John, Trinity College, Hartford, Conn. (23). 1875.
Brooks, Major Thomas B., Geol. State Surveys, Mich. and Wis., Newburgh, N. Y. (26). 1879.

[1] The date at the end of the line indicates the year when the member was made a Fellow.

Bross, Hon. Wm., Chicago, Ill. (7). 1874.
Broun, Prof. W. LeRoy, Vanderbilt Univ., Nashville, Tenn. (25). 1877.
Brown, Robert, jr., Office Gas Light Co., Cincinnati, Ohio (11). 1874.
Brown, Mrs. Robert, jr., Cincinnati, Ohio (17). 1874.
Brush, Prof. George J., Yale College, New Haven, Conn. (4). 1874.
Burgess, Edward, Sec. Natural History Soc., Boston, Mass (22). 1877.
Burnham, S. W., 52 Vincennes Ave., Chicago, Ill. (25). 1877.

Caldwell, Prof. Geo. C., Cornell University, Ithaca, N. Y. (23). 1875.
Canby, Wm. M., 1101 Delaware Avenue, Wilmington, Del. (17). 1878.
Carmichael, Prof. Henry, Bowdoin College, Brunswick, Me. (21). 1875.
Carpenter, Lieut. W. L., U. S. A., Dunkirk, N. Y. (24). 1877.
Carr, Lucien, Peabody Mus. Arch. and Ethn., Cambridge, Mass. (25). 1877.
Chadbourne, Prof. P. A., Pres't Williams Coll., Williamstown, Mass. (10). 1875.
Chamberlin, T. C., Beloit College, Beloit, Wis. (21). 1877.
Chandler, Prof. C. F., School of Mines, Columbia Coll., N. Y. (19). 1875.
Chandler, Prof. W. H., The Lehigh Univ., Bethlehem, Pa. (19). 1874.
Chanute, O., care Erie Railway, New York, N. Y. (17). 1877.
Chesbrough, E. S., Chicago, Ill. (2). 1877.
Chickering, Prof. J. W., jr., Deaf Mute College, Washington, D. C. (22). 1877.
Clark, Prof. John E., Mathematics, Yale College, New Haven, Conn. (17). 1875.
Clarke, Prof. F. W., Cincinnati University, Cincinnati, Ohio (18). 1874.
Coffin, Prof. John H. C., U. S. Navy, Washington, D. C. (1). 1874.
Coffin, Prof. Selden J., Ph.D., Lafayette College, Easton, Pa. (22). 1874.
Collett, Prof. John, Chief Ind. Bureau of Statistics of Geology, Indianapolis, Ind. (17). 1874.
Comstock, Prof. M. L., Ph. D., Galesburg, Knox Co., Ill. (21). 1874.
Comstock, Prof. Theo. B., Eureka, San Juan Co., Col. (24). 1877.
Cook, Prof. George H., New Brunswick, N. J. (4). 1875.
Cope, Prof. Edward D., 2100 Pine St., Philadelphia, Pa. (17). 1875.
Cox, Prof. Edward T., Indianapolis, Ind. (19). 1874.
Cramp, Rev. J. M., D.D., Wolfville, N. S. (11). 1874.
Crocker, Charles F., Lawrence, Mass. (22). 1874.
Crocker, Susan E., M.D., Lawrence, Mass. (21). 1874.
Cummings, Rev. Joseph, D.D., 82 Prospect St., Cambridgeport, Mass. (13). 1874.
Curtis, Dr. Josiah, Washington, D. C. (18). 1874.
Cutting, Hiram A., M.D., State Geologist, Lunenburgh, Vt. (17). 1874.

Dall, Mrs. Caroline H., 399 Delaware Ave., Buffalo, N. Y. (18). 1874.
Dall, Wm. H., Smithsonian Institution, Washington, D. C. (18). 1874.
Dalrymple, Rev. Dr. E. A., Baltimore, Md. (11). 1874.

Dana, Edward Salisbury, New Haven, Conn. (23). 1875.
Dana, Prof. James D., New Haven, Conn. (1). 1875.
Danforth, Edward, Dep't of Public Instruction, Elmira, N. Y. (11). 1874.
Dawson, Dr. J. W., Principal McGill Coll., Montreal, Canada (10). 1875.
Dean, George W., U. S. Coast Survey, Fall River, Mass. (15). 1874.
Dimmock, George, 19 Baldwin St., Cambridge, Mass. (22). 1874.
Dinwiddie, Robert, 113 Water St., New York, N. Y. (1). 1874.
Draper, Henry, M.D., 271 Madison Ave., New York, N. Y. (28). 1879.
Dutton, Capt. C. E., U. S. Ord. Dep't, Washington, D. C. (23). 1875.
Dwyer, John, M. D., Hartford, Conn. (23). 1874.

Eastman, Prof. J. R., U. S. Naval Observatory, Washington, D. C. (26) 1879.
Eaton, Prof. D. G., Packer Institute, Brooklyn, N. Y. (19). 1874.
Eddy, Prof. H. T., University of Cincinnati, Cincinnati, Ohio (24). 1875.
Edison, Thos. A., Menlo Park, N. J. (27). 1878.
Egleston, Prof. Thos., School of Mines, Columbia College, New York, N. Y. (27). 1879.
Eimbeck, Wm., U.S.C.S., Washington, D. C. (17). 1874.
Elliott, Ezekiel B., Statistical Bureau, Washington, D. C. (10). 1874.
Elsberg, Louis, M.D., 614 Fifth Avenue, New York, N. Y. (23). 1874.
Emerson, Prof. Benjamin K., Amherst, Mass. (19). 1877.
Emerson, Prof. C. F., Dartmouth College, Hanover, N. H. (22). 1874.
Emerton, James H., Salem, Mass. (18). 1875.
Emmons, S. F., P. O. Box 2218, Cheyenne, Wyoming Territory (26). 1879.
Engelmann, Dr. George, St. Louis, Mo. (1). 1875.
Engelmann, Geo. J., M. D., 3003 Locust St., St. Louis, Mo. (25). 1878.
Eustis, Prof. Henry L., Cambridge, Mass. (2). 1874.
Evans, Asher B., Principal Union School, Lockport, N. Y. (19). 1874.

Fairbanks, Rev. Henry, St. Johnsbury, Vt. (14). 1874.
Farlow, Dr. W. G., 6 Park Square, Boston, Mass. (20). 1875.
Farmer, Moses G., Torpedo Station, Newport, R. I. (9). 1875.
Ferrel, Wm., U. S. Coast Survey Office, Washington, D. C. (11). 1875.
Ficklin, Prof. Joseph, Univ. of Missouri, Columbia, Mo. (20). 1878.
Fitch, Edward H., Ashtabula, Ohio (11). 1874.
Fitch, O. H., Ashtabula, Ohio (7). 1874.
Fontaine, Prof. W. M., Univ. of W. Va., Morgantown, W. Va. (25). 1877.
Foote, Dr. A. E., 1223 Belmont Avenue, Philadelphia, Pa. (21). 1874.
Forbes, Prof. S. A., Normal, Ill. (27). 1879.
Frazer, Prof. Persifor, jr., Ass't Geologist, 2d Geol. Survey of Pa., 917 Clinton St., Philadelphia, Pa. (24). 1879.
Freeman, H. C., Alto Pass, Union Co., Ill. (17). 1876.

Gardiner, Rev. Frederic, D.D., Middletown, Conn. (23). 1874.

Gardner, James T., Director N. Y. State Survey, Albany, N. Y. (25). 1879.
Garland, Landon C., Chancellor Vanderbilt Univ., Nashville, Tenn. (25). 1877.
Garman, S. W., Museum Comp. Zoology, Cambridge, Mass. (20). 1874.
Genth, Prof. F. A., Univ. of Pennsylvania, Philadelphia, Pa. (24). 1875.
Gilbert, G. K., P. O. Box 591, Washington, D. C. (18). 1874.
Gillman, Henry, 155 Adams Avenue East, Detroit, Mich. (24). 1875.
Gilman, Daniel C., President of the Johns Hopkins University, Baltimore, Md. (10). 1875.
Goessman, Prof. C. A., Mass. Agric. Coll., Amherst, Mass. (18). 1875.
Goodale, Prof. G. L., Botanic Gardens, Cambridge, Mass. (18). 1875.
Goode, Prof. George Brown, Middletown, Conn. (22). 1874.
Goodfellow, Edward, Ass't U. S. Coast and Geodetic Survey, Washington, D. C. (24). 1879.
Grant, Mrs. Mary J., Brookfield, Conn. (23). 1874.
Gray, Prof. Asa, Botanic Gardens, Cambridge, Mass. (1). 1875.
Green, Dr. Traill, Easton, Pa. (1). 1874.
Grimes, J. Stanley, 165 Mason St., Milwaukee, Wis. (17). 1874.
Grinnan, A. G., Orange Court House, Va. (7). 1875.
Grote, Aug. R., Director of the Museum Buffalo Society Natural Sciences, Buffalo, N. Y. (22). 1875.
Guyot, Prof. Arnold, Princeton, N. J. (1). 1875.

Hagen, Dr. Hermann A., Mus. Comp. Zool., Cambridge, Mass. (17). 1875.
Haldeman, Prof. S. S., Chickies, Pa. (1). 1874.
Hall, Prof. Asaph, U. S. Naval Observ., Washington, D. C. (25). 1877.
Hall, Prof. James, Albany, N. Y. (1). 1875.
Hambly, John B., Portsmouth, R. I. (18). 1874.
Hamlin, Dr. A. C., Bangor, Me. (10). 1874.
Harger, Oscar, Yale College Museum, New Haven, Conn. (25). 1879.
Harkness, Prof. Wm., U. S. N., U. S. Observatory, Washington, D. C. (26). 1878.
Harrington, Prof. Mark W., Ann Arbor, Mich. (22). 1875.
Harrison, Dr. B. F., Wallingford, Conn. (11). 1874.
Hasbrouck, Prof. I. E., Rutgers Coll., New Brunswick, N. J. (23). 1874.
Hastings, C. S., Johns Hopkins University, Baltimore, Md. (25). 1878.
Hawes, George W., New Haven, Conn. (23). 1875.
Hedrick, B. S., Exam'r U. S. Pat. Office, Washington, D. C. (19). 1874.
Henshaw, Henry W., Care Major J. M. Powell, 910 M St., Washington, D. C. (24). 1877.
Herrick, Mrs. Sophie B., Baltimore, Md. (23). 1877.
Hervey, Rev. A. B., Taunton, Mass. (22). 1879.
Hilgard, Prof. J. E., U. S. Coast Survey, Washington, D. C. (4). 1874.
Hill, George W., Nautical Almanac Office, Navy Department, Washington, D. C. (23). 1874.
Hill, Rev. Dr. Thomas, 68 Deering St., Portland, Me. (3). 1875.

Hinrichs, Prof. Gustavus, State University, Iowa City, Iowa (17). 1874.
Hitchcock, Prof. Charles H., Hanover, N. H. (11). 1874.
Holden, Prof. E. S., Naval Observatory, Washington, D. C. (23). 1875.
Horsford, Prof. E. N., Cambridge, Mass. (1). 1876.
Hosford, Charles E., Terre Haute, Ind. (20). 1874.
Hough, Franklin B., Lowville, N. Y. (4). 1874.
Hough, G. W. (15). 1874.
Hoy, Philo R., M.D., Racine, Wis. (17). 1875.
Hunt, George, Providence, R. I. (9). 1874.
Hunt, Dr. T. Sterry, Montreal, Canada (1). 1874.
Huntington, Prof. J. H., Box 1914, Boston, Mass. (19). 1874.
Hyatt, James, Stanfordville, Duchess Co., N. Y. (10). 1874.

Irving, Roland D., Wisconsin State Geol. Survey, Madison, Wis. (26). 1879.

James, Thomas Potts, Cambridge, Mass. (22). 1879.
Jenks, Elisha T., Middleborough, Mass. (22). 1874.
Jenks, Prof. J. W. P., Middleborough, Mass. (2). 1874.
Johnson, Prof. S. W., Sheffield Sci. School, New Haven, Conn. (22). 1874.
Joy, Prof. Charles A., Stockbridge, Mass. (8). 1879.
Julien, A. A., School of Mines, Columbia Coll., New York, N. Y. (24). 1875.

Kerr, Prof. W. C., Raleigh, N. C. (10). 1874.
Kirkwood, Prof. Daniel, Bloomington, Ind. (7). 1874.

Lambert, Rev. Thomas R., D.D., Charlestown, Mass. (18). 1874.
Langley, Prof. J. W., Univ. of Michigan, Ann Arbor, Mich. (23). 1875.
Langley, Prof. S. P., Director of Observatory, Allegheny, Pa. (18). 1874.
Lattimore, Prof. S. A., Univ. of Rochester, Rochester, N. Y. (15). 1874.
Lawrence, George N., 172 Pearl St., New York, N. Y. (7). 1877.
Laws, Samuel S., Pres. Univ. of Missouri, Columbia, Mo. (23). 1874.
Lea, Dr. Isaac, 1622 Locust St., Philadelphia, Pa. (1). 1875.
LeConte, Dr. John L., 1625 Spruce St., Philadelphia, Pa. (1). 1874.
Leeds, Prof. Albert R., Stevens Institute, Hoboken, N. J. (23). 1874.
Leonard, N. R., State University, Iowa City, Iowa (21). 1875.
Lesley, Prof. J. Peter, State Geol. of Pa., 1008 Clinton St., Philadelphia, Pa. (2). 1874.
Levette, Dr. Gilbert M., Geologist, Indianapolis, Ind. (23). 1874.
Lindsley, Dr. J. B., Nashville, Tenn. (1). 1874.
Lintner, J. A., N. Y. State Mus. of Nat. Hist., Albany, N. Y. (22). 1874.
Little, Prof. Geo., State Geologist of Georgia, Atlanta, Ga. (15). 1874.

Little, W. C., Albany, N. Y. (22). 1874.
Litton, Abram, Washington University, St. Louis, Mo. (28). 1879.
Lockwood, Rev. Samuel, Freehold, Monmouth Co., N. J. (18). 1875.
Loomis, Prof. Elias, New Haven, Conn. (1). 1874.
Loughridge, Prof. R. H., Ass't State Geologist, Atlanta, Ga. (21). 1874.
Lovering, Prof. Joseph, Harvard University, Cambridge, Mass. (2). 1875.
Lupton, Prof. N. T., Vanderbilt University, Nashville, Tenn. (17). 1874.
Lyman, Prof. Chester S., New Haven, Conn. (4). 1875.
Lyman, Col. Theodore, Brookline, Mass. (28). 1875.
Lyon, Dr. Henry, 34 Monument Sq., Charlestown, Mass. (18). 1874.

Mann, B. Pickman, 19 Follen St., Cambridge, Mass. (22). 1874.
Marcy, Oliver, LL.D., Evanston, Ill. (10). 1874.
Marsh, Prof. O. C., Yale College, New Haven, Conn. (15). 1874.
Mason, Prof. Otis T., Columbian University, Washington, D. C. (25). 1877.
Mayer, Prof. A. M., So. Orange, N. J. (19). 1874.
McMurtrie, William, Dep't Agriculture, Washington, D. C. (22). 1874.
Means, A., D.D., LL.D., Oxford, Ga. (5). 1877.
Meehan, Thomas, Germantown, Pa. (17). 1875.
Mees, Carl Leo, Louisville, Ky. (24). · 1876.
Meigs, Dr. James Aitken, 1408 Spruce St., Philadelphia, Pa. (12). 1875.
Mendenhall, Prof. T. C., Imperial University, Tokio, Japan (20). 1874.
Michelson, A. A., Ensign U. S. N., Nautical Almanac Office, Washington, D. C. (26). 1879.
Mitchell, Miss Maria, Vassar College, Poughkeepsie, N. Y. (4). 1874.
Moore, Prof. J. W., M. D., Lafayette College, Easton, Pa. (22). 1874.
Morgan, Hon. L. H., Rochester, N. Y. (10). 1875.
Morley, Prof. Edward W., Hudson, Ohio (18). 1876.
Morris, Rev. John G., Baltimore, Md. (12). 1874.
Morse, Prof. E. S., Salem, Mass. (18). 1874.
Morton, H., Stevens Institute Technology, Hoboken, N. J. (18). 1875.
Munroe, Prof. C. E., U. S. Naval Academy, Annapolis, Md. (22). 1874.

Nason, Prof. H. B., Rensselaer Polytechnic Inst., Troy, N. Y. (13). 1874.
Nelson, Prof. Edward T., Delaware, Delaware Co., Ohio (24). 1877.
Newcomb, Prof. S., U. S. Naval Observ., Washington, D. C. (13). 1874.
Newton, Hubert A., New Haven, Conn. (6). 1874.
Nichols, Prof. W. R., Mass. Inst. Technology, Boston, Mass. (18). 1875.
Niles, Prof. W. H., Cambridge, Mass. (16). 1874.
Nipher, Prof. F. E., Washington University, St. Louis, Mo. (24). 1876.
Norton, Prof. W. A., New Haven, Conn. (6). 1875.

Oliver, Prof. James E., Cornell University, Ithaca, N. Y. (7). 1875.

Oliver, Miss Mary E., Cascadilla Hotel, Ithaca, N. Y. (20). 1874.
Ordway, Prof. John M., Mass. Inst. Technology, Boston, Mass. (9). 1875
Orton, Prof. Edward, President Ohio Agricultural and Mechanical College, Columbus, Ohio (19). 1875.
Osborne, J. W., 212 Delaware Ave. N. E., Washington, D. C. (22). 1874.
Owen, Dr. R., New Harmony, Ind. (20). 1874.

Paine, Cyrus F., Rochester, N. Y. (12). 1874.
Paine, Nathaniel, Worcester, Mass. (18). 1874.
Palfray, Hon. Charles W., Salem, Mass. (21). 1874.
Parkhurst, H. M., Law Stenographer, 31 Park Row, New York, N. Y. (23). 1874.
Parry, Dr. Charles C., Davenport, Iowa (6). 1875.
Peckham, S. F., Univ. of Minnesota, Minneapolis, Minn. (18). 1875.
Pedrick, Wm. R., Lawrence, Mass. (22). 1875.
Peirce, B. O., Beverly, Mass. (18). 1874.
Perkins, Maurice, Schenectady, N. Y. (15). 1875.
Pettee, Prof. William H., Ann Arbor, Mich. (24). 1875.
Phillips, A. W., New Haven, Conn. (24). 1879.
Phippen, Geo. D., Salem, Mass. (18). 1874.
Pickering, Prof. E. C., Director of Observ., Cambridge, Mass. (18). 1875.
Powell, Major J. W., 910 M St., Washington, D. C. (23). 1875.
Prescott, Prof. Albert B., Ann Arbor, Mich. (23). 1875.
Prime, Frederick, jr., Ass't Geologist of Pa., 907 Walnut St., Philadelphia, Pa. (24). 1875.
Pulsifer, Wm. H., St. Louis, Mo. (26). 1879.
Pumpelly, Prof. Raphael, U. S. Geol. Survey, Newport, R. I. (17). 1875.
Putnam, F. W., Curator Peabody Museum Archæology and Ethnology, Cambridge, Mass. Address as Permanent Secretary A. A. A. S., Salem, Mass. (10). 1874.
Pynchon, Rev. T. R., Pres't of Trinity Coll., Hartford, Conn. (23). 1875.

Quimby, Prof. E. T., Hanover, N. H. (22). 1874.
Quincy, Edmund, 85 Clinton St., Boston, Mass. (11). 1874.

Rauch, Dr. John H., Chicago, Ill. (11). 1875.
Raymond, Rossiter W., 17 Burling Slip, New York, N. Y. (15). 1875.
Redfield, J. H., care A. Whitney and Sons, Philadelphia, Pa. (1). 1874.
Rees, Prof. John K., Washington University, St. Louis, Mo. (26). 1878.
Remsen, Prof. Ira, John Hopkins University, Baltimore, Md. (22). 1875.
Rice, Prof. Wm. North, Middletown, Conn. (18). 1874.
Richards, Prof. Robert H., Mass. Inst. Tech., Boston, Mass. (22). 1875.

Richards, Mrs. R. H., Mass. Inst. of Tech., Boston, Mass. (23). 1878.
Riley, Prof. C. V., U. S. Entomologist, Washington, D. C. (17). 1874.
Ritchie, E. S., 150 Tremont St., Boston, Mass. (10). 1877.
Rockwood, Prof. Charles G., jr., Princeton, N. J. (20). 1874.
Rogers, Fairman, Newport, R. I. (11). 1874.
Rogers, Prof. Robert E., Univ. of Pa., Philadelphia, Pa. (18). 1874.
Rogers, W. A., Ass't Harvard College Observ., Cambridge, Mass. (15). 1875.
Rogers, Prof. Wm. B., 117 Marlborough St., Boston, Mass. (1). 1874.
Rominger, Dr. Carl, Ann Arbor, Mich. (21). 1879.
Rood, Prof. O. N., Cor. E. 49th St. & Madison Ave., New York, N. Y. (14). 1875.
Roosevelt, Clinton, 11 Wall St., New York, N. Y. (11). 1874.
Runkle, Prof. J. D., Mass. Inst. of Tech., Boston, Mass. (2). 1875.
Rutherford, Lewis M., 175 Second Ave., New York, N. Y. (13). 1875.

Sadtler, Prof. S. P., University of Pa., Philadelphia, Pa. (22). 1875.
Safford, Dr. James M., Nashville, Tenn. (6). 1875.
Saunders, William, London, Ontario, Canada (17). 1874.
Schott, Charles A., Coast Survey Office, Washington, D. C. (8). 1874.
Schweitzer, Prof. Paul, State Univ. of Mo., Columbia, Mo. (24). 1877.
Scudder, Samuel H., Cambridge, Mass. (13). 1874.
Seaman, W. H., Microscopist, 1424 11th St. N. W., Washington, D. C. (23). 1874.
Shaler, Prof. N. S., Harvard University, Cambridge, Mass. (19). 1875.
Sheafer, P. W., Pottsville, Pa. (4). 1879.
Sias, Solomon, M.D., Schoharie, Schoharie Co., N. Y. (10). 1874.
Sill, Hon. Elisha N., Cuyahoga Falls, Ohio (6). 1874.
Silliman, Prof. Benj., Yale College, New Haven, Conn. (1). 1874.
Silliman, Prof. Justus M., Lafayette College, Easton, Pa. (19). 1874.
Smith, Prof. E. A., University of Alabama, Tuscaloosa, Ala. (20). 1877.
Smith, Dr. J. Lawrence, Louisville, Ky. (1). 1874.
Smith, Prof. S. I., Yale College, New Haven, Conn. (18). 1875.
Smock, Prof. John Conover, Rutgers College, New Brunswick, N. J. (23). 1879.
Spencer, J. W., Teacher & Geol., Paxton, Sullivan Co., Ind. (20). 1874.
Stanard, Benjamin A., Cleveland, Ohio (6). 1874.
Stearns, Henry P., M.D., Hartford, Conn. (23). 1874.
Stearns, R. E. C., P. O. Box 13, Berkeley, Cal. (18). 1874.
Steiner, Dr. Lewis H., Frederick City, Md. (7). 1874.
Stephens, W. Hudson, Lowville, N. Y. (18). 1874.
Stockwell, John N., 579 Case Avenue, Cleveland, Ohio (18). 1875.
Stone, Mrs. Leander, 1552 Indiana Avenue, Chicago, Ill. (22). 1874.
Stone, Ormond, Director Cincinnati Observatory, Univ. of Cincinnati, Mt. Lookout, Ohio (24). 1876.
Storrs, Henry E., Jacksonville, Ill. (20). 1874.

Stuart, Prof. A. P. S., Lincoln, Nebraska (21). 1874.
Stubbs, Prof. William C., Alabama Agricultural and Mechanical College, Auburn, Lee Co., Ala. (25). 1877.

Tappan, Prof. Eli T., Kenyon College, Gambier, Ohio (20). 1874.
Terry, Prof. N. M., U. S. Naval Academy, Annapolis, Md. (23). 1874.
Thompson, A. Remsen, 50 West 51st Street, New York, N. Y. (1). 1874.
Thurston, Prof. R. H., Stevens Institute, Hoboken, N. J. (23). 1875.
Trowbridge, Prof. John, Harvard University, Cambridge, Mass. (25). 1876.
Tuttle, Prof. Albert H., Columbus, Ohio (17). 1874.

Uhler, Philip R., Baltimore, Md. (19). 1874.

Van der Weyde, Dr. P. H., P. O. Box 4379, New York, N. Y. (17). 1874.
Van Vleck, Prof. John M., Middletown, Conn. (23). 1875.
Vaux, William S., 1702 Arch St., Philadelphia, Pa. (1). 1875.
Verrill, Prof. A. E., Yale College, New Haven, Conn. (16). 1875
Vose, Prof. Geo. L., Bowdoin College, Brunswick, Me. (15). 1875.

Wadsworth, M. Edward, Ph. D., Assistant in Lithology, Museum of Comparative Zoology, Cambridge, Mass. (23). 1874.
Walker, Prof. J. R., 154 Canal St., New Orleans, La. (19). 1874.
Waller, E., School of Mines, Columbia College, New York, N. Y. (23). 1874.
Walling, H. F., 102 Chauncy St., Boston, Mass. (16). 1874.
Ward, Prof. Henry A., Rochester, N. Y. (13). 1875.
Ward, Lester F., Treasury Dep't, Washington, D. C. (26). 1879.
Ward, Dr. R. H., 53 Fourth St., Troy, N. Y. (17). 1874.
Warner, James D., 199 Baltic St., Brooklyn, N. Y. (18). 1874.
Warren, Gen. G. K., U.S.A., Engineer's Office, Newport, R. I. (12). 1875.
Warren, Prof. S. Edward, Newton, Mass. (17). 1875.
Watson, Sereno, Botanic Gardens, Cambridge, Mass. (22). 1875.
Webster, Prof. N. B., Principal Webster Inst., Norfolk, Va. (7). 1874.
Wells, Daniel H., Hartford, Conn. (18). 1875.
Wetherby, Albert G., Univ. of Cincinnati, Cincinnati, Ohio (26). 1877.
Wheatland, Dr. Henry, President Essex Inst., Salem, Mass. (1). 1874.
Wheeler, Capt. Geo. M., U. S. E., Lock Box 93, Washington, D. C. (25). 1879.
Wheildon, W. W., Concord, Mass. (13). 1874.
White, Prof. C. A., Le Droit Park, Washington, D. C. (17). 1875.
Whitfield, R. P., Am. Mus. Nat. Hist., 77th St. & 8th Avenue, N. Y. (18). 1874.

Whitney, Solon F., Watertown, Mass. (20). 1874.
Whittlesey, Col. Charles, Historical Rooms, Cleveland, Ohio (1). 1875.
Wilber, G. M., Pine Plains, N. Y. (19). 1874.
Wilbur, A. B., Port Jervis, Orange Co., N. Y. (23). 1874.
Wilder, Prof. Burt G., Cornell University, Ithaca, N. Y. (22). 1875.
Wiley, Prof. Harvey W., Purdue Univ., Lafayette, Ind. (21). 1874.
Williams, Charles H., M.D., 15 Arlington St., Boston, Mass. (22). 1874.
Williams, Prof. Henry W., 15 Arlington St., Boston, Mass. (11). 1874.
Wilson, Prof. Daniel, 117 Bloor St., Toronto, Canada (25). 1876.
Winchell, Prof. Alex., Ann Arbor, Mich. (3). 1875.
Winchell, Prof. N. H., Univ. of Minnesota, Minneapolis, Minn. (19). 1874.
Witter, F. M., Muscatine, Iowa (21). 1875.
Wormley, T. G., Univ. of Pennsylvania, Philadelphia, Pa. (20). 1878.
Worthen, A. H., Springfield, Ill. (5). 1874.
Wright, Prof. Arthur W., Yale College, New Haven, Conn. (14). 1874.
Würtele, Rev. Louis C., Acton Vale, Province of Quebec, Can. (11). 1875.
Wyckoff, Wm. C., 44 Howard St., New York, N. Y. (20). 1874.
Wylie, Prof. Theoph. A., Indiana Univ., Bloomington, Ind. (20). 1874.

Yarrow, Dr. H. C., care Army Med. Mus., Washington, D. C. (23). 1874.
Youmans, Prof. Edward L., New York, N. Y. (6). 1874.
Young, C. A., Prof. of Astronomy, College of New Jersey, Princeton, New Jersey (18). 1874.

[353 FELLOWS.]

TOTAL NUMBER OF MEMBERS OF THE ASSOCIATION, 1030.

DECEASED MEMBERS.

[Information respecting omissions in this list, and the date of birth and of decease of any of the former members, is requested by the Permanent Secretary.]

Abbe, George W., New York, N. Y. (23). Died Sept. 25, 1879.
Abert, J. J., Washington, D. C. (1). Died in 1862.
Adams, C. B., Amherst, Mass. (1).
Adams, Edwin F., Charlestown, Mass. (18).
Adams, Samuel, Jacksonville, Ill. (18). Born Dec. 19, 1806. Died April 29, 1877.
Agassiz, Louis, Cambridge, Mass. (1). Born May 28, 1807. Died Dec. 14, 1873.
Ainsworth, J. G., Barry, Mass. (14).
Allston, R. F. W., Georgetown, S. C. (3). Died in 1864.
Anthony, Charles H., Albany, N. Y. (6). Died in 1874.
Ames, N. P., Springfield, Mass. (1).
Appleton, Nathan, Boston, Mass. (1).
Armstrong, John W., Fredonia, N. Y. (24).
Atwater, Mrs. S. T., Chicago, Ill. (17). Born Aug. 8, 1812. Died April 11, 1878.

Bache, Alexander D., Washington, D. C. (1). Born July 19, 1806. Died Feb. 17, 1867.
Bache, Franklin, Philadelphia, Pa. (1).
Bailey, J. W., West Point, N. Y. (1).
Bardwell, F. W., Lawrence, Kan. (13.) Died in 1878.
Barrett, Moses, Milwaukee, Wis. (21). Died in 1878.
Beck, C. F., Philadelphia, Pa. (1).
Beck, Lewis C., New Brunswick, N. J. (1).
Beck, T. Romeyn, Albany, N. Y. (1).
Belt, Thomas, London, Eng. (27). Died Sept 8, 1878.
Benedict, G. W., Burlington, Vt. (16).
Bicknell, Edwin, Boston, Mass. (18). Born in 1830. Died March 19, 1877.
Binney, Amos, Boston, Mass. (1).
Binney, John, Boston, Mass. (3).
Blake, Homer C., New York, N. Y. (28).
Blanding, William, ———, R. I. (1).
Blatchford, Thomas W., Troy, N. Y. (6).
Blatchley, Miss S. L., New Haven, Conn. (19).

Boadle, John, Haddonfield, N. J. (20). Born in 1805. Died in July, 1878.
Bomford, George, Washington, D. C. (1).
Bowron, James, South Pittsburg, Tenn. (26). Died in Dec., 1877.
Bradley, Leverette, Jersey City, N. J. (15). Died in 1875.
Braithwaite, Jos., Chambly, C. W. (11).
Brigham, Charles H., Ann Arbor, Mich. (17). Born in 1820. Died in Jan., 1879.
Brown, Andrew, Natchez, Miss. (1).
Burnap, G. W., Baltimore, Md. (12).
Burnett, Waldo I., Boston, Mass. (1).
Butler, Thomas B., Norwalk, Conn. (10).

Cairns, F. A., New York, N. Y. (27). Died in 1879.
Carpenter, Thornton, Camden, S. C. (7).
Carpenter, William M., New Orleans, La. (1).
Case, William, Cleveland, Ohio (6).
Caswell, Alexis, Providence, R. I. (2). Died Jan. 8, 1877.
Chapman, N., Philadelphia, Pa. (1).
Chase, S., Dartmouth, N. H. (2).
Chauvenet, William, St. Louis, Mo. (1).
Clapp, Asahel, New Albany, Ind. (1).
Clark, H. J., Cambridge, Mass. (13).
Clark, Joseph, Cincinnati, Ohio (5).
Clarke, A. B., Holyoke, Mass. (13).
Cleaveland, C. H., Cincinnati, Ohio (9).
Cleveland, A. B., Cambridge, Mass. (2).
Coffin, James H., Easton, Pa. (1).
Cole, Thomas, Salem, Mass. (1). Born Dec. 24, 1779. Died June 24, 1852.
Coleman, Henry, Boston, Mass. (1).
Conrad, Timothy Abbott, Philadelphia, Pa. (1). Born in August, 1803. Died August 9, 1877.
Cooke, Caleb, Salem, Mass. (18). Born Feb. 5, 1838. Died June 5, 1880.
Cooper, William, Hoboken, N. J. (9). Died in 1864.
Corning, Erastus, Albany, N. Y. (6).
Couper, J. Hamilton, Darien, Ga. (1).
Crosby, Alpheus, Salem, Mass. (10). Born Oct. 13, 1810. Died Apr. 17, 1874.
Crosby, Thomas R., Hanover, N. H. (18).
Croswell, Edwin, Albany, N. Y. (6).
Curry, W. F., Geneva, N. Y. (11).

Dayton, Edwin A., Madrid, N. Y. (7). Born in 1827. Died June 24, 1873.
Dean, Amos, Albany, N. Y. (6).
Dearborn, George H. A. S., Roxbury, Mass. (1).
Dekay, James E., New York, N. Y. (1).

DeLaski, John, Carver's Harbor, Me. (18).
Dewey, Chester, Rochester, N. Y. (1).
Dexter, G. M., Boston, Mass. (11).
Dillingham, W. A. P., Augusta, Me. (17).
Doggett, Wm. E., Chicago, Ill. (17). Born Nov. 20, 1820. Died in 1876.
Doolittle, L., Lenoxville, C. E. (11). Died in 1862.
Ducatel, J. T., Baltimore, Md. (1).
Duffield, George, Detroit, Mich. (10). Died in 1868.
Dumont, A. H., Newport, R. I. (14).
Duncan, Lucius C., New Orleans, La. (10).
Dunn, R. P., Providence, R. I. (14).

Easton, Norman, Fall River, Mass. (14).
Eaton, James H., Beloit, Wis. (17). Died Jan. 5, 1877.
Ely, Charles Arthur, Elyria, Ohio (4).
Emmons, Ebenezer, Williamstown, Mass. (1).
Engstrom, A. B., Burlington, N. J. (1).
Everett, Edward, Boston, Mass. (2).
Ewing, Thomas, Lancaster, Ohio (5).

Faries, R. J., Wauwatosa, Wis. (21). Died May 31, 1878.
Ferris, Isaac, New York, N. Y. (6).
Feuchtwanger, Lewis, New York, N. Y. (11). Died in 1876.
Fillmore, Millard, Buffalo, N. Y. (7).
Fisher, Mark, Trenton, N. J. (10).
Fitch, Alexander, Hartford, Conn. (1).
Forbush, E. B., Buffalo, N. Y. (15).
Force, Peter, Washington, D. C. (4.)
Ford, A. C., Nashville, Tenn. (26).
Foster, J. W., Chicago, Ill. (1). Died June 29, 1873.
Foucon, Felix, Madison, Wis. (18).
Fowle, Wm. B., Boston, Mass. (1). Died in 1864.
Fox, Charles, Grosse Ile, Mich. (7).
Frazer, John F., Philadelphia, Pa. (1).
French, J. W., West Point, N. Y. (11).

Gavit, John E., New York, N. Y. (1).
Gay, Martin, Boston, Mass. (1).
Gibbon, J. H., Charlotte, N. C. (3).
Gillespie, W. M., Schenectady, N. Y. (10.)
Gilmor, Robert, Baltimore, Md. (1).
Gould, Augustus A., Boston, Mass. (11). Died Sept. 15, 1866.
Gould, B. A., Boston, Mass. (2).
Graham, James D., Washington, D. C. (1).

Gray, Alonzo, Brooklyn, N. Y. (13).
Gray, James H., Springfield, Mass. (6).
Greene, Benjamin D., Boston, Mass. (1).
Greene, Everett W., Madison, N. J. (10). Died in 1864.
Greene, Samuel, Woonsocket, R. I. (9). Died in 1868.
Greer, James, Dayton, Ohio (20).
Griffith, Robert E., Philadelphia, Pa. (1).
Griswold, John A., Troy, N. Y. (19).
Guest, William E., Ogdensburg, N. Y. (6).

Hackley, Charles W., New York, N. Y. (4).
Hale, Enoch, Boston, Mass. (1).
Hance, Ebenezer, Fallsington P. O., Pa. (7). Died in 1876.
Hare, Robert, Philadelphia, Pa. (11).
Harlan, Joseph G., Haverford, Pa. (8).
Harlan, Richard, Philadelphia, Pa. (1).
Harris, Thaddeus W., Cambridge, Mass. (1). Born Nov. 12, 1795. Died Jan. 16, 1856.
Harrison, Jos., jr., Philadelphia, Pa. (12).
Hart, Simeon, Farmington, Conn. (1).
Hartt, Charles F., Ithaca, N. Y. (18). Born in 1840. Died March 18, 1878.
Haven, Joseph, Chicago, Ill. (17). Died in 1874.
Hayden, H. H., Baltimore, Md. (1).
Hayward, James, Boston, Mass. (1).
Henry, Jos., Washington, D. C. (1). Born Dec. 17, 1797. Died May 13, 1878.
Hickox, S. V. R., Chicago, Ill. (17). Died in 1872.
Hilgard, Theo. C., St. Louis, Mo. (17).
Hincks, William, Toronto, C. W. (11).
Hitchcock, Edward, Amherst, Mass. (1).
Hodgson, W. B., Savannah, Ga. (10).
Holbrook, J. E., Charleston, S. C. (1).
Hopkins, Albert, Williamstown, Mass. (19).
Hopkins, James G., Ogdensburg, N. Y. (10). Died in 1860.
Hopkins, T. O., Williamsville, N. Y. (10). Died in 1866.
Hosford, Benj. F., Haverhill, Mass. (13). Died in 1864.
Horton, C. V. R., Chaumont, N. Y. (10). Died in 1862.
Horton, William, Craigville, N. Y. (1).
Houghton, Douglas, Detroit, Mich. (1).
Hovey, Edmund O., Crawfordsville, Ind. (20). Born July 15, 1801. Died March 10, 1877.
Howland, Theodore, Buffalo, N. Y. (15).
Hubbert, James, Richmond, Province of Quebec (16). Died in 1868.
Hunt, E. B., Washington, D. C. (2).
Hunt, Freeman, New York, N. Y. (11).

Ives, Moses B., Providence, R. I. (9). Died in 1857.

Ives, Thomas P., Providence, R. I. (10).

Johnson, W. R., Washington, D. C. (1).
Jones, Catesby A. R., Washington, D. C. (8).

Keely, G. W., Waterville, Me. (1).
Keep, N. C., Boston, Mass. (13). Died in 1875.
Kennicott, Robert, West Northfield, Ill. (12).
King, Mitchell, Charleston, S. C. (3). Died in 1862.
Klippart, John H., Columbus, Ohio (17). Died October, 1878.
Knickerbocker, Charles, Chicago, Ill. (17). Died in 1873.
Knight, J. B., Philadelphia, Pa. (21). Died March 10, 1879.

Lacklan, R., Cincinnati, Ohio (11).
Lapham, Increase A., Milwaukee, Wis. (3). Born Mch. 7, 1811. Died Sept. 14, 1875.
LaRoche, R., Philadelphia, Pa. (12).
Lasel, Edward, Williamstown, Mass. (1).
Lawford, Frederick, Montreal, Canada (11). Died in 1866.
Lederer, Baron von, Washington, D. C. (1).
Lieber, Oscar M., Columbia, S. C. (8).
Lincklaen, Ledyard, Cazenovia, N. Y. (1).
Linsley, James H., Stafford, Conn. (1).
Lockwood, Moses B., Providence, R. I. (9). Died in 1872.
Logan, William E., Montreal, Canada (1).
Loosey, Charles F., New York, N. Y. (12).
Lothrop, Joshua R., Buffalo, N. Y. (15).
Lyon, Sidney S., Jeffersonville, Ind. (20).

Maack, G. A., Cambridge, Mass. (18).
Mahan, D. H., West Point, N. Y. (9). Died in 1871.
Marsh, Dexter, Greenfield, Mass. (1).
Marsh, James E., Roxbury, Mass. (10).
Mather, William W., Columbus, Ohio (1).
Maupin, S., Charlottesville, Va. (10).
McMahon, Mathew, Albany, N. Y. (11).
M'Conihe, Isaac, Troy, N. Y. (5).
Meade, George G., Philadelphia, Pa. (15).
Meek, F. B., Washington, D. C. (6). Born December 10, 1817. Died December 21, 1876.
Mitchell, O. M., Cincinnati, Ohio (3).
Mitchell, William, Poughkeepsie, N. Y. (3). Died in 1869.
Mitchell, Wm. H., Florence, Ala. (17).

Morton, S. G., Philadelphia, Pa. (1).
Mudge, Benjamin F., Manhattan, Kansas (25). Died Nov. 21, 1879, aged 62 years.
Munroe, Nathan, Bradford, Mass. (6). Died in 1866.
Munroe, William, Concord, Mass. (18). Died April 27, 1877.

Newton, E. H., Cambridge, N. Y. (1).
Nichols, C. A., Providence, R. I. (17). Died in 1877.
Nicholson, Thomas, New Orleans, La. (21).
Nicollett, J. N., Washington, D. C. (1).
Norton, J. P., New Haven, Conn. (1).
Noyes, J. O., New Orleans, La. (21).
Nutt, Cyrus, Bloomington, Ind. (20). Died in 1875.

Oakes, Wm., Ipswich, Mass. (1). Born July 1, 1799. Died July 31, 1848.
Ogden, Robert W., New Orleans, La. (21). Died March 24, 1878.
Ogden, William B., High Bridge, Westchester Co., N. Y. (17). Born in 1805. Died Aug. 3, 1877.
Olmsted, Alexander F., New Haven, Conn. (4).
Olmsted, Denison, New Haven, Conn. (1).
Olmsted, Denison, jr., New Haven, Conn. (1).

Painter, Jacob, Lima, Pa. (23). Died in 1876.
Painter, Minshall, Lima, Pa. (7).
Parker, Wilbur F., West Meriden, Conn. (23). Died in 1876.
Parkman, Samuel, Boston, Mass. (1).
Perkins, George R., Utica, N. Y. (1). Died in 1876.
Perkins, Henry C., Newburyport, Mass. (18). Born Nov. 13, 1804. Died Feb. 2, 1873.
Perry, John B., Cambridge, Mass. (16).
Perry, M. C., New York, N. Y. (10).
Piggot, A. Snowden, Baltimore, Md. (10).
Plumb, Ovid, Salisbury, Conn. (9).
Pope, Charles A., St. Louis, Mo. (12).
Porter, John A., New Haven, Conn. (14).
Pourtalès, Louis François de, Cambridge, Mass. (1). Died July 18, 1880, in the 58th year of his age.
Pruyn, John V. L., Albany, N. Y. (1). Born in 1811. Died in 1877.
Pugh, Evan, Centre Co., Pa. (14).
Putnam, Mrs. F. W., Cambridge, Mass. (19). Born Dec. 29, 1838. Died March 10, 1879.

Read, Ezra, Terra Haute, Ind. (20). Died in 1877.

Redfield, William C., New York, N. Y. (1).
Resor, Jacob, Cincinnati, Ohio (8). Died in 1871.
Robb, James, Fredericton, N. B. (4).
Robinson, Coleman T., Buffalo, N. Y. (15).
Rockwell, John A., Norwich, Conn. (10).
Rogers, Henry D., Glasgow, Scotland (1).
Rogers, James B., Philadelphia, Pa. (1).

Sager, Abram, Ann Arbor, Mich. (6). Died in 1877.
Schaeffer, Geo. C., Washington, D. C. (1). Died in 1873.
Scott, Joseph, Dunham, C. E. (11). Died in 1865.
Senter, Harvey S., Aledo, Ill. (20). Died in 1875.
Seward, William H., Auburn, N. Y. (1).
Sherwin, Thomas, Dedham, Mass. (11). Died in 1869.
Silliman, Benjamin, New Haven, Conn. (1).
Skinner, John B., Buffalo, N. Y. (15). Died in 1871.
Slack, J. H., Philadelphia, Pa. (12).
Smith, James Y., Providence, R. I. (9). Died in 1876.
Smith, J. V., Cincinnati, Ohio (5).
Smith, Lyndon A., Newark, N. J. (9).
Snell, Ebenezer S., Amherst, Mass. (2). Died in 1877.
Sparks, Jared, Cambridge, Mass. (2).
Stimpson, William, Chicago, Ill. (12). Died May 26, 1872.
Stone, Samuel, Chicago, Ill. (17). Died in 1876.
Sullivant, W. S., Columbus, Ohio (7).
Swain, James, Fort Dodge, Iowa (21). Born in 1816. Died in 1877.

Tallmadge, James, New York, N. Y. (1).
Taylor, Richard C., Philadelphia, Pa. (1).
Tenney, Sanborn, Williamstown, Mass. (17). Born in January, 1827. Died July 11, 1877.
Teschemacher, J. E., Boston, Mass. (1).
Thompson, Alexander, Aurora, N. Y. (6).
Thompson, Z., Burlington, Vt. (1).
Thurber, Isaac, Providence, R. I. (9).
Tillman, Samuel D., Jersey City, N. J. (15). Died in 1875.
Tolderoy, James B., Fredericton, N. B. (11).
Torrey, John, New York, N. Y. (1).
Torrey, Joseph, Burlington, Vt. (2). Died Nov. 26, 1867.
Totten, J. G., Washington, D. C. (1).
Townsend, Howard, Albany, N. Y. (10). Died in 1867.
Townsend, John K., Philadelphia, Pa. (1).
Townsend, Robert, Albany, N. Y. (9). Died in 1866.
Troost, Gerard, Nashville, Tenn. (1). Born March 15, 1776. Died Aug. 14, 1850.

[illegible], M., Tuscaloosa, Ala. (1).
[illegible], Edward H., New Haven, Conn. (1).

[illegible], John W., Dayton, Ohio (1).
[illegible], [illegible], Bristol, Pa. (1).

[illegible], James S., Geneseo, N. Y. (2).
[illegible], [illegible], Philadelphia, Pa. (9).
[illegible], [illegible], Cleves, N. Y. (10).
[illegible], [illegible], Washington, D. C. (1).
[illegible], [illegible], Cincinnati, Ohio (4).
[illegible], [illegible], Rock Island, Ill. (17).
[illegible], [illegible], [illegible], Conn. (18). Born April 17, 1796. Died March [illegible]
[illegible], [illegible], [illegible], Mass. (1). Born Aug. 1, 1778. Died May 4, [illegible]
[illegible], [illegible], [illegible], Pa. (1)
[illegible], [illegible], [illegible], N. Y. (1)
[illegible], [illegible], [illegible], Mass. (1)
[illegible], [illegible], [illegible], N. Y. (1)
[illegible], [illegible], [illegible], Mass. (1). Died in [illegible]
[illegible], [illegible], [illegible], Pa. (1)
[illegible], [illegible], [illegible], Pa. (1). Died in [illegible]
[illegible], [illegible], [illegible], N. Y. (1). Born [illegible]. Died April 14, [illegible]
[illegible], [illegible], [illegible], Pa. (1)
[illegible], [illegible], [illegible], Mass. (1). Died in [illegible]
[illegible], [illegible], [illegible], N. Y. (1)
[illegible], [illegible], [illegible], Pa. (1)
[illegible], [illegible], [illegible], Mass. (1). Died [illegible]. [illegible]

[illegible], [illegible], [illegible], [illegible], [illegible], Mass. (1). Died Jan. 1, [illegible]
[illegible], [illegible], [illegible], [illegible], [illegible], Pa. (1)

[illegible], [illegible], [illegible], Mass. (1)

ADDRESS

OF

PROFESSOR O. C. MARSH,

THE RETIRING PRESIDENT OF THE ASSOCIATION.

LADIES AND GENTLEMEN:—

IN the rapid progress of knowledge, we are constantly brought face to face with the question, What is Life? The answer is not yet, but a thousand earnest seekers after truth seem to be slowly approaching a solution. This question gives a new interest to every department of science that relates to life in any form, and the history of life offers a most suggestive field for research. One line of investigation lies through embryology, and here the advance is most encouraging. Another promising path leads back through the life history of the globe, and in this direction we may hope for increasing light, as a reward for patient work.

The plants and animals now living on the earth interest alike the savage and the savant, and hence have been carefully observed in every age of human history. The life of the remote past, however, is preserved only in scanty records, buried in the earth, and therefore readily escapes attention. For these reasons, the study of ancient life is one of the latest of modern sciences, and among the most difficult. In view of the great advances which this department of knowledge has made within the last decade, especially in this country, I have thought it fitting to the

present occasion to review briefly its development, and have chosen for my subject this evening, THE HISTORY AND METHODS OF PALÆONTOLOGICAL DISCOVERY.

In the short time now at my command, I can only attempt to present a rapid sketch of the principal steps in the progress of this science. The literature of the subject, especially in connection with the discussions it provoked, is voluminous, and an outline of the history itself must suffice for my present purpose.

In looking over the records of Palæontology, its history may conveniently be divided into four periods, well marked by prominent features, but, like all stages of intellectual growth, without definite boundaries.

The first period, dating back to the time when men first noticed fossil remains in the rocks, and queried as to their nature, is of special historic interest. The most prominent characteristic of this period was, a long and bitter contest as to the *nature of fossil remains*. Were they mere "sports of Nature," or had they once been endowed with life? Simple as this problem now seems, centuries passed before the wise men of that time were agreed upon its solution.

Sea shells in the solid rock on the tops of mountains early attracted the attention of the ancients, and the learned men among them seem to have appreciated in some instances their true character, and given rational explanations of their presence.

The philosopher Zenophanes, of Colophon, who lived about 500 B. C., mentions the remains of fishes and other animals in the stone quarries near Syracuse, the impression of an anchovy in the rock of Paros, and various marine fossils at other places. His conclusion from these facts was, that the surface of the earth had once been in a soft condition at the bottom of the sea; and thus the objects mentioned were entombed. Herodotus, half a century later, speaks of marine shells on the hills of Egypt, and over the Libyan desert, and he inferred therefrom that the sea had once covered that whole region. Empedocles, of Agrigentum (450 B. C.), believed that the many hippopotamus bones found in Sicily were remains of human giants, in comparison with which the present race were as children. Here, he thought, was a battle field between the gods and the Titans, and the bones

belonged to the slain. Pythagoras (582 B. C.) had already anticipated one conclusion of modern geology, if the following statement, attributed to him by Ovid, was his own :[1]

> Vidi ego quod fuerat quondam solidissima tellus,
> Esse fretum : vidi factas ex æquore terras ;
> Et procul a pelago conchæ jacuere marinæ.

Aristotle (384–322 B. C.) was not only aware of the existence of fossils in the rocks, but has also placed on record sagacious views as to the changes in the earth's surface necessary to account for them. In the second book of his Meteorics, he says: "The changes of the earth are so slow in comparison to the duration of our lives, that they are overlooked; and the migrations of people after great catastrophes and their removal to other regions, cause the event to be forgotten." Again, in the same work, he says: "As time never fails, and the universe is eternal, neither the Tanais, nor the Nile, can have flowed forever. The places where they rise were once dry, and there is a limit to their operations: but there is none to time. So of all other rivers; they spring up, and they perish; and the sea also continually deserts some lands and invades others. The same tracts, therefore, of the earth are not, some always sea, and others always continents, but everything changes in the course of time."

Aristotle's views on the subject of spontaneous generation were less sound, and his doctrines on this subject exerted a powerful influence for the succeeding twenty centuries. In the long discussion that followed concerning the nature of fossil remains, Aristotle's views were paramount. He believed that animals could originate from moist earth or the slime of rivers, and this seemed to the people of that period a much simpler way of accounting for the remains of animals in the rocks, than the marvellous changes of sea and land otherwise required to explain their presence. Aristotle's opinion was in accordance with the Biblical account of the creation of Man out of the dust of the earth, and hence more readily obtained credence.

Theophrastus, a pupil of Aristotle, alludes to fossil fishes found near Heraclea, in Pontus, and in Paphlagonia, and says: "They were either developed from fish spawn left behind in the earth, or gone astray from rivers or the sea into cavities of the earth, where

[1] Metamorphoses, Liber XV, 262.

they had become petrified." In treating of fossil ivory and bones, the same writer supposed them to be produced by a certain plastic virtue latent in the earth. To this same cause, as we shall see, many later authors attributed the origin of all fossil remains.

Previous to this, Anaximander, the Miletian philosopher, who was born about 610 years before Christ, had expressed essentially the same view. According to both Plutarch and Censorinus, Anaximander taught that fishes, or animals very like fishes, sprang from heated water and earth, and from these animals came the human race; a statement which can hardly be considered as anticipating the modern idea of evolution, as some authors have imagined.

The Romans added but little to the knowledge possessed by the Greeks in regard to fossil remains. Pliny (23–79 A. D.), however, seems to have examined such objects with interest, and in his renowned work on Natural History gave names to several forms. He doubtless borrowed largely from Theophrastus, who wrote about three hundred years before. Among the objects named by Pliny were, "*Bucardia*, like to an ox's heart;" "*Brontia*, resembling the head of a tortoise, supposed to fall in thunder storms;" "*Glossoptra*, similar to a human tongue, which does not grow in the earth, but falls from heaven while the moon is eclipsed;" "the *Horn of Ammon*, possessing, with a golden color, the figure of a ram's horn;" *Ceraunia* and *Ombria*, supposed to be thunderbolts; *Ostracites*, resembling the oyster shell; *Spongites*, having the form of sponge; *Phycites*, similar to seaweed or rushes. He also mentions stones resembling the teeth of hippopotamus; and says that Theophrastus speaks of fossil ivory, both black and white, of bones born in the earth, and of stones bearing the figure of bones.

Tertullian (160 A. D.) mentions instances of the remains of sea animals on the mountains, far from the sea, but uses them as a proof of the general deluge recorded in Scripture.

During the next thirteen or fourteen centuries, fossil remains of animals and plants seemed to have attracted so little attention, that few references are made to them by the writers of this period. During these ages of darkness, all departments of knowledge suffered alike, and feeble repetitions of ideas derived from the

ancients seem to have been about the only contributions of that period to Natural Science.

Albert the Great (1205–1280 A. D.), the most learned man of his time, mentions that a branch of a tree was found, on which was a bird's nest containing birds, the whole being solid stone. He accounted for this strange phenomenon by the *vis formativa* of Aristotle, an occult force, which, according to the prevalent notions of the time, was capable of forming most of the extraordinary objects discovered in the earth.

Alexander *ab Alexandro*, of Naples, states that he saw, in the mountains of Calabria, a considerable distance from the sea, a variegated hard marble, in which many sea shells but little changed were heaped, forming one mass with the marble.

With the beginning of the sixteenth century, a great impetus was given to the investigation of organic fossils, especially in Italy, where this study really began. The discovery of fossil shells, which abound in this region, now attracted great attention, and a fierce discussion soon arose as to the true nature of these and other remains. The ideas of Aristotle in regard to spontaneous generation, and especially his view of the hidden forces of the earth, which he claimed had power to produce such remains, now for the first time were seriously questioned, although it was not till nearly two centuries later that these doctrines lost their dominant influence.

Leonardo da Vinci, the renowned painter and philosopher, who was born in 1452, strongly opposed the commonly accepted opinions as to the origin of organized fossils. He claimed that the fossil shells under discussion were what they seemed, and had once lived at the bottom of the sea: "You tell me," he says, "that Nature and the influence of the stars have formed these shells in the mountains; then show me a place in the mountains where the stars at the present day make shelly forms of different ages, and of different species in the same place." Again, he says, "In what manner can such a cause account for the petrifactions in the same place of various leaves, sea-weeds, and marine crabs?"

In 1517, excavations in the vicinity of Verona brought to light many curious petrifactions, which led to much speculation as to their nature and origin. Among the various authors who wrote on this subject was Fracastoro, who declared that the fossils once

belonged to living animals, which had lived and multiplied where found. He ridiculed the prevailing ideas that the plastic force of the ancients could fashion stones into organic forms. Some writers claimed that these shells had been left by Noah's flood, but to this idea Fracastoro offered a mass of evidence, which would now seem conclusive, but which then only aroused bitter hostility. That inundation, he said, was too transient; it consisted mainly of fresh water; and if it had transported shells to great distances, must have scattered them over the surface, not buried them in the interior of mountains.

Conrad Gesner (1516–1565), whose history of animals has been considered the basis of modern zoology, published at Zurich in 1565 a small but important work entitled "*De omni rerum fossilium genere.*" It contained a catalogue of the collection of fossils made by John Kentmann. This is the oldest catalogue of fossils with which I am acquainted.

George Agricola (1494–1555) was, according to Cuvier, the first mineralogist who appeared after the revival of learning in Europe. In his great work, "*De Re Metallica*," published in 1546, he mentions various fossil remains, and says they were produced by a certain "*materia pinguis*," or fatty matter, set in fermentation by heat. Some years later, Bauhin published a descriptive catalogue of the fossils he had collected in the neighborhood of Boll, in Wurtemberg.[2]

Andrew Mattioli, a distinguished botanist, adopted Agricola's notion as to the origin of organized fossils, but admitted that shells and bones might be turned into stone by being permeated by a "lapidifying juice." Falloppio, the eminent professor of anatomy at Padua, believed that fossil shells were generated by fermentation where they were found; and that the tusks of elephants, dug up near Apulia, were merely earthy concretions. Mercati, in 1574, published figures of the fossil shells preserved in the Museum of the Vatican, but expressed the opinion that they were only stones, that owed their peculiar shapes to the heavenly bodies. Olivi, of Cremona, described the fossils in the Museum at Verona, and considered them all "sports of nature."

Palissy, a French author, in 1580, opposed these views, and is said to have been the first to assert in Paris that fossil shells and

[2] *Historia novi et admirabilis Fontis Balneique Bollensis, in Ducatu Wirtembergico. Montbéliard,* 1598.

fishes had once belonged to marine animals. Fabio Colonna appears to have first pointed out that some of the fossil shells found in Italy were marine, and some terrestrial.

Another peculiar theory discussed in the sixteenth century deserves mention. This was the vegetation theory, especially advocated by Tournefort and Camerarius, both eminent as botanists. These writers believed that the seeds of minerals and fossils were diffused throughout the sea and the earth, and were developed into their peculiar forms by the regular increment of their particles, similar to the formation of crystals. "How could the *Cornu Ammonis*," Tournefort asked, "which is constantly in the figure of a volute, be formed without a seed containing the same structure in the small, as in the larger forms? Who moulded it so artfully, and where are the moulds?" The stalactites which formed in caverns in various parts of the world were also supposed to be proofs of this vegetative growth.

Still another theory has been held at various times, and is not yet entirely forgotten, namely: that the Creator made fossil animals and plants just as they are found in the rocks, in pursuance of a plan beyond our comprehension. This theory has never prevailed among those familiar with scientific facts, and hence needs here no further consideration.

An interest in fossil remains arose in England later than on the continent; but when attention was directed to them, the first opinions as to their origin were not less fanciful and erroneous than those to which we have already referred. Dr. Plot, in his "Natural History of Oxfordshire," published in 1677, considered the origin of fossil shells and fishes to be due to a "plastic virtue, latent in the earth," as Theophrastus had suggested long before. Lhwyd, in his "*Lithophylacii Britannici Ichnographia*," published at Oxford in 1699, gives a catalogue of English fossils contained in the Ashmolean Museum. He opposed the *vis plastica* theory, and expressed the opinion that the spawn of fishes and other marine animals had been raised with the vapors from the sea, conveyed inland by clouds, and deposited by rain, had permeated into the interior of the earth, and thus produced the fossil remains we find in the rocks. About this time several important works were published in England by Dr. Martin Lister, which did much to diffuse a true knowledge of fossil remains. He gave figures of recent shells side by side with some of the fossil forms, so that the resemblance became at once apparent. The fossil species of

Tuomey, M., Tuscaloosa, Ala. (1).
Tyler, Edward R., New Haven, Conn. (1).

Vancleve, John W., Dayton, Ohio (1).
Vanuxem, Lardner, Bristol, Pa. (1).

Wadsworth, James S., Genesee, N. Y. (2).
Wagner, Tobias, Philadelphia, Pa. (9).
Walker, Joseph, Oxford, N. Y. (10).
Walker, Sears C., Washington, D. C. (1).
Walker, Timothy, Cincinnati, Ohio (4).
Walsh, Benjamin D., Rock Island, Ill. (17).
Wanzer, Ira, Brookfield, Conn. (18). Born April 17, 1796. Died March 5, 1879.
Warren, John C., Boston, Mass. (1). Born Aug. 1, 1778. Died May 4, 1856.
Watertown, Charles, Wakefield, Eng. (1).
Webster, H. B., Albany, N. Y. (1).
Webster, J. W., Cambridge, Mass. (1).
Webster, M. H., Albany, N. Y. (1).
Weed, Monroe, Wyoming, N. Y. (6). Died in 1867.
Weyman, G. W., Pittsburg, Pa. (6). Died in 1864.
Wheatland, Richard H., Salem, Mass. (13).
Whitman, Wm. E., Philadelphia, Pa. (23). Died in 1875.
Whitney, Asa, Philadelphia, Pa. (1).
Whittlesey, Charles C., St. Louis, Mo. (11). Died in 1872.
Willard, Emma, Troy, N. Y. (15). Born Feb. 23, 1787. Died April 15, 1870.
Wilson, W. C., Carlisle, Pa. (12).
Winlock, Joseph, Cambridge, Mass. (5). Died in 1875.
Woodbury, L., Portsmouth, N. H. (1).
Woodman, John S., Hanover, N. H. (11). Died in 1871.
Wright, John, Troy, N. Y. (1).
Wyman, Jeffries, Cambridge, Mass. (1). Born Aug. 11, 1814. Died Sept. 4, 1874.

Yarnall, M., Washington, D. C. (26). Born in 1817. Died Jan. 27, 1879.
Young, Ira, Hanover, N. H. (7).

ADDRESS

OF

PROFESSOR O. C. MARSH,

THE RETIRING PRESIDENT OF THE ASSOCIATION.

LADIES AND GENTLEMEN:—

IN the rapid progress of knowledge, we are constantly brought face to face with the question, What is Life? The answer is not yet, but a thousand earnest seekers after truth seem to be slowly approaching a solution. This question gives a new interest to every department of science that relates to life in any form, and the history of life offers a most suggestive field for research. One line of investigation lies through embryology, and here the advance is most encouraging. Another promising path leads back through the life history of the globe, and in this direction we may hope for increasing light, as a reward for patient work.

The plants and animals now living on the earth interest alike the savage and the savant, and hence have been carefully observed in every age of human history. The life of the remote past, however, is preserved only in scanty records, buried in the earth, and therefore readily escapes attention. For these reasons, the study of ancient life is one of the latest of modern sciences, and among the most difficult. In view of the great advances which this department of knowledge has made within the last decade, especially in this country, I have thought it fitting to the

present occasion to review briefly its development, and have chosen for my subject this evening, THE HISTORY AND METHODS OF PALÆONTOLOGICAL DISCOVERY.

In the short time now at my command, I can only attempt to present a rapid sketch of the principal steps in the progress of this science. The literature of the subject, especially in connection with the discussions it provoked, is voluminous, and an outline of the history itself must suffice for my present purpose.

In looking over the records of Palæontology, its history may conveniently be divided into four periods, well marked by prominent features, but, like all stages of intellectual growth, without definite boundaries.

The first period, dating back to the time when men first noticed fossil remains in the rocks, and queried as to their nature, is of special historic interest. The most prominent characteristic of this period was, a long and bitter contest as to the *nature of fossil remains*. Were they mere "sports of Nature," or had they once been endowed with life? Simple as this problem now seems, centuries passed before the wise men of that time were agreed upon its solution.

Sea shells in the solid rock on the tops of mountains early attracted the attention of the ancients, and the learned men among them seem to have appreciated in some instances their true character, and given rational explanations of their presence.

The philosopher Zenophanes, of Colophon, who lived about 500 B. C., mentions the remains of fishes and other animals in the stone quarries near Syracuse, the impression of an anchovy in the rock of Paros, and various marine fossils at other places. His conclusion from these facts was, that the surface of the earth had once been in a soft condition at the bottom of the sea; and thus the objects mentioned were entombed. Herodotus, half a century later, speaks of marine shells on the hills of Egypt, and over the Libyan desert, and he inferred therefrom that the sea had once covered that whole region. Empedocles, of Agrigentum (450 B. C.), believed that the many hippopotamus bones found in Sicily were remains of human giants, in comparison with which the present race were as children. Here, he thought, was a battle field between the gods and the Titans, and the bones

belonged to the slain. Pythagoras (582 B. C.) had already anticipated one conclusion of modern geology, if the following statement, attributed to him by Ovid, was his own:[1]

> Vidi ego quod fuerat quondam solidissima tellus,
> Esse fretum: vidi factas ex æquore terras;
> Et procul a pelago conchæ jacuere marinæ.

Aristotle (384–322 B. C.) was not only aware of the existence of fossils in the rocks, but has also placed on record sagacious views as to the changes in the earth's surface necessary to account for them. In the second book of his Meteorics, he says: "The changes of the earth are so slow in comparison to the duration of our lives, that they are overlooked; and the migrations of people after great catastrophes and their removal to other regions, cause the event to be forgotten." Again, in the same work, he says: "As time never fails, and the universe is eternal, neither the Tanais, nor the Nile, can have flowed forever. The places where they rise were once dry, and there is a limit to their operations: but there is none to time. So of all other rivers; they spring up, and they perish; and the sea also continually deserts some lands and invades others. The same tracts, therefore, of the earth are not, some always sea, and others always continents, but everything changes in the course of time."

Aristotle's views on the subject of spontaneous generation were less sound, and his doctrines on this subject exerted a powerful influence for the succeeding twenty centuries. In the long discussion that followed concerning the nature of fossil remains, Aristotle's views were paramount. He believed that animals could originate from moist earth or the slime of rivers, and this seemed to the people of that period a much simpler way of accounting for the remains of animals in the rocks, than the marvellous changes of sea and land otherwise required to explain their presence. Aristotle's opinion was in accordance with the Biblical account of the creation of Man out of the dust of the earth, and hence more readily obtained credence.

Theophrastus, a pupil of Aristotle, alludes to fossil fishes found near Heracléa, in Pontus, and in Paphlagonia, and says: "They were either developed from fish spawn left behind in the earth, or gone astray from rivers or the sea into cavities of the earth, where

[1] Metamorphoses, Liber XV, 262.

they had become petrified." In treating of fossil ivory and bones, the same writer supposed them to be produced by a certain plastic virtue latent in the earth. To this same cause, as we shall see, many later authors attributed the origin of all fossil remains.

Previous to this, Anaximander, the Miletian philosopher, who was born about 610 years before Christ, had expressed essentially the same view. According to both Plutarch and Censorinus, Anaximander taught that fishes, or animals very like fishes, sprang from heated water and earth, and from these animals came the human race; a statement which can hardly be considered as anticipating the modern idea of evolution, as some authors have imagined.

The Romans added but little to the knowledge possessed by the Greeks in regard to fossil remains. Pliny (23–79 A. D.), however, seems to have examined such objects with interest, and in his renowned work on Natural History gave names to several forms. He doubtless borrowed largely from Theophrastus, who wrote about three hundred years before. Among the objects named by Pliny were, "*Bucardia*, like to an ox's heart;" "*Brontia*, resembling the head of a tortoise, supposed to fall in thunder storms;" "*Glossoptra*, similar to a human tongue, which does not grow in the earth, but falls from heaven while the moon is eclipsed;" "the *Horn of Ammon*, possessing, with a golden color, the figure of a ram's horn;" *Ceraunia* and *Ombria*, supposed to be thunderbolts; *Ostracites*, resembling the oyster shell; *Spongites*, having the form of sponge; *Phycites*, similar to seaweed or rushes. He also mentions stones resembling the teeth of hippopotamus; and says that Theophrastus speaks of fossil ivory, both black and white, of bones born in the earth, and of stones bearing the figure of bones.

Tertullian (160 A. D.) mentions instances of the remains of sea animals on the mountains, far from the sea, but uses them as a proof of the general deluge recorded in Scripture.

During the next thirteen or fourteen centuries, fossil remains of animals and plants seemed to have attracted so little attention, that few references are made to them by the writers of this period. During these ages of darkness, all departments of knowledge suffered alike, and feeble repetitions of ideas derived from the

ancients seem to have been about the only contributions of that period to Natural Science.

Albert the Great (1205–1280 A. D.), the most learned man of his time, mentions that a branch of a tree was found, on which was a bird's nest containing birds, the whole being solid stone. He accounted for this strange phenomenon by the *vis formativa* of Aristotle, an occult force, which, according to the prevalent notions of the time, was capable of forming most of the extraordinary objects discovered in the earth.

Alexander *ab Alexandro*, of Naples, states that he saw, in the mountains of Calabria, a considerable distance from the sea, a variegated hard marble, in which many sea shells but little changed were heaped, forming one mass with the marble.

With the beginning of the sixteenth century, a great impetus was given to the investigation of organic fossils, especially in Italy, where this study really began. The discovery of fossil shells, which abound in this region, now attracted great attention, and a fierce discussion soon arose as to the true nature of these and other remains. The ideas of Aristotle in regard to spontaneous generation, and especially his view of the hidden forces of the earth, which he claimed had power to produce such remains, now for the first time were seriously questioned, although it was not till nearly two centuries later that these doctrines lost their dominant influence.

Leonardo da Vinci, the renowned painter and philosopher, who was born in 1452, strongly opposed the commonly accepted opinions as to the origin of organized fossils. He claimed that the fossil shells under discussion were what they seemed, and had once lived at the bottom of the sea: "You tell me," he says, "that Nature and the influence of the stars have formed these shells in the mountains; then show me a place in the mountains where the stars at the present day make shelly forms of different ages, and of different species in the same place." Again, he says, "In what manner can such a cause account for the petrifactions in the same place of various leaves, sea-weeds, and marine crabs?"

In 1517, excavations in the vicinity of Verona brought to light many curious petrifactions, which led to much speculation as to their nature and origin. Among the various authors who wrote on this subject was Fracastoro, who declared that the fossils once

belonged to living animals, which had lived and multiplied where found. He ridiculed the prevailing ideas that the plastic force of the ancients could fashion stones into organic forms. Some writers claimed that these shells had been left by Noah's flood, but to this idea Fracastoro offered a mass of evidence, which would now seem conclusive, but which then only aroused bitter hostility. That inundation, he said, was too transient; it consisted mainly of fresh water; and if it had transported shells to great distances, must have scattered them over the surface, not buried them in the interior of mountains.

Conrad Gesner (1516–1565), whose history of animals has been considered the basis of modern zoology, published at Zurich in 1565 a small but important work entitled "*De omni rerum fossilium genere.*" It contained a catalogue of the collection of fossils made by John Kentmann. This is the oldest catalogue of fossils with which I am acquainted.

George Agricola (1494–1555) was, according to Cuvier, the first mineralogist who appeared after the revival of learning in Europe. In his great work, "*De Re Metallica,*" published in 1546, he mentions various fossil remains, and says they were produced by a certain "*materia pinguis,*" or fatty matter, set in fermentation by heat. Some years later, Bauhin published a descriptive catalogue of the fossils he had collected in the neighborhood of Boll, in Wurtemberg.[2]

Andrew Mattioli, a distinguished botanist, adopted Agricola's notion as to the origin of organized fossils, but admitted that shells and bones might be turned into stone by being permeated by a "lapidifying juice." Falloppio, the eminent professor of anatomy at Padua, believed that fossil shells were generated by fermentation where they were found; and that the tusks of elephants, dug up near Apulia, were merely earthy concretions. Mercati, in 1574, published figures of the fossil shells preserved in the Museum of the Vatican, but expressed the opinion that they were only stones, that owed their peculiar shapes to the heavenly bodies. Olivi, of Cremona, described the fossils in the Museum at Verona, and considered them all "sports of nature."

Palissy, a French author, in 1580, opposed these views, and is said to have been the first to assert in Paris that fossil shells and

[2] *Historia novi et admirabilis Fontis Balneique Bollensis, in Ducatu Wirtembergico. Montbéliard,* 1598.

fishes had once belonged to marine animals. Fabio Colonna appears to have first pointed out that some of the fossil shells found in Italy were marine, and some terrestrial.

Another peculiar theory discussed in the sixteenth century deserves mention. This was the vegetation theory, especially advocated by Tournefort and Camerarius, both eminent as botanists. These writers believed that the seeds of minerals and fossils were diffused throughout the sea and the earth, and were developed into their peculiar forms by the regular increment of their particles, similar to the formation of crystals. "How could the *Cornu Ammonis*," Tournefort asked, "which is constantly in the figure of a volute, be formed without a seed containing the same structure in the small, as in the larger forms? Who moulded it so artfully, and where are the moulds?" The stalactites which formed in caverns in various parts of the world were also supposed to be proofs of this vegetative growth.

Still another theory has been held at various times, and is not yet entirely forgotten, namely: that the Creator made fossil animals and plants just as they are found in the rocks, in pursuance of a plan beyond our comprehension. This theory has never prevailed among those familiar with scientific facts, and hence needs here no further consideration.

An interest in fossil remains arose in England later than on the continent; but when attention was directed to them, the first opinions as to their origin were not less fanciful and erroneous than those to which we have already referred. Dr. Plot, in his "Natural History of Oxfordshire," published in 1677, considered the origin of fossil shells and fishes to be due to a "plastic virtue, latent in the earth," as Theophrastus had suggested long before. Lhwyd, in his "*Lithophylacii Britannici Ichnographia*," published at Oxford in 1699, gives a catalogue of English fossils contained in the Ashmolean Museum. He opposed the *vis plastica* theory, and expressed the opinion that the spawn of fishes and other marine animals had been raised with the vapors from the sea, conveyed inland by clouds, and deposited by rain, had permeated into the interior of the earth, and thus produced the fossil remains we find in the rocks. About this time several important works were published in England by Dr. Martin Lister, which did much to diffuse a true knowledge of fossil remains. He gave figures of recent shells side by side with some of the fossil forms, so that the resemblance became at once apparent. The fossil species of

shells he called "turbinated and bivalve stones," and adds, "either these were terriginous, or, if otherwise, the animals which they so exactly represent have become extinct."

During the seventeenth century there was a considerable advance in the study of fossil remains. The discussions in regard to the nature and origin of these objects, had called attention to them, and many collections were now made, especially in Italy, and also in Germany, where a strong interest in this subject had been aroused. Catalogues of these collections were not unfrequently published, and some of them were illustrated with such accurate figures, that many of the species can now be readily recognized. In this century, too, an important step in advance was made by the collection and description of fossils from particular localities and regions, in distinction from general collections of curiosities.

Casper Schwenkfeld, in 1600, published a catalogue of the fossils discovered in Silesia; in 1622, a detailed description of the renowned Museum of Calceolarius, of Verona, appeared; and in 1642, a catalogue of Besler's collection. Wormius's catalogue was published in 1652; Spener's in 1663; and Septala's in 1666. A description of the Museum of the King of Denmark was issued in 1669; Cottorp's catalogue in 1674; and that of the renowned Kirscher in 1678. Dr. Grew gave an account in 1687 of the specimens in the Museum of Gresham's College in England; and in 1695, Petiver of London published a catalogue of his very extensive collection. A catalogue by Fred. Lauchmund, on the fossils of Hildeshein, appeared in 1669, and the fossils of Switzerland were described by John Jacob Wagner in 1689. Among similar works, were the dissertations of Gyer, at Frankfort, and Albertus, at Leipsic.

Steno, a Dane, who had been professor of anatomy at Padua, published, in 1669, one of the most important works of this period.[3] He entered earnestly into the controversy as to the origin of fossil remains, and by dissecting a shark from the Mediterranean, proved that its teeth were identical with some found fossil in Tuscany. He also compared the fossil shells found in Italy with existing species, and pointed out their resemblance. In the same work, Steno expressed some very important views in

[3] *De solido intra solidum naturaliter contento.*

regard to the different kinds of strata, and their origin, and first placed on record the important fact that the oldest rocks contain no fossils.

Scilla, the Sicilian painter, published in 1670 a work on the fossils of Calabria, well illustrated. He is very severe against those who doubted the organic origin of fossils, but is inclined to consider them relics of the Mosaic deluge.

Another instance of the power of the *lusus naturæ* theory, even at the close of the seventeenth century, deserves mention. In the year 1696, the skeleton of a fossil elephant was dug up at Tonna, near Gotha, in Germany, and was described by William Ernest Tentzel, a teacher in the Gotha Gymnasium. He declared the bones to be the remains of an animal that had lived long before. The Medical Faculty in Gotha, however, considered the subject, and decided officially that this specimen was only a freak of nature.

Beside the authors I have mentioned, there were many others who wrote about fossil remains before the close of the seventeenth century, and took part in the general discussion as to their nature and origin. During the progress of this controversy the most fantastic theories were broached and stoutly defended, and although refuted from time to time by a few clear-headed men, continually sprang up anew, in the same or modified forms. The influence of Aristotle's views of equivocal generation, and especially the scholastic tendency to disputation, so prevalent during the middle ages, had contributed largely to the retardation of progress, and yet a real advance in knowledge had been made. The long contest in regard to the nature of fossil remains was essentially over, for the more intelligent opinion at the time now acknowledged that these objects were not mere "sports of nature," but had once been endowed with life. At this point, therefore, the first period in the history of Palæontology, as I have indicated it, may appropriately end.

It is true that later still, the old exploded errors about the plastic force and fermentation were from time to time revived, as they have been almost to the present day; but learned men, with few exceptions, no longer seriously questioned that fossils were real organisms, as the ancients had once believed. The many collections of fossils that had been brought together, and the illustrated works that had been published about them, were a

foundation for greater progress, and, with the eighteenth century, the second period in the history of Palæontology began.

The main characteristic of this period was the general belief, that *fossil remains were deposited by the Mosaic deluge*. We have seen that this view had already been advanced, but it was not till the beginning of the eighteenth century that it became the prevailing view. This doctrine was strongly opposed by some courageous men, and the discussion on the subject soon became even more bitter than the previous one, as to the nature of fossils.

In this diluvial discussion theologians and laymen alike took part. For nearly a century the former had it all their own way, for the general public, then as now, believed what they were taught. Noah's flood was thought to have been universal, and was the only general catastrophe of which the people of that day had any knowledge or conception.

The scholars among them were of course familiar with the accounts of Deucalion and his ark, in a previous deluge, as we are to-day with similar traditions held by various races of men. The firm belief that the earth and all it contains was created in six days; that all life on the globe was destroyed by the deluge, except alone what Noah saved; and that the earth and its inhabitants were to be destroyed by fire, was the foundation on which all knowledge of the earth was based. With such fixed opinions, the fossil remains of animals and plants were naturally regarded as relics left by the flood described in Holy Writ. The dominant nature of this belief is seen in nearly all the literature in regard to fossils published at this time, and some of the works which then appeared have become famous on this account.

In 1710, David Büttner published a volume entitled "*Rudera Diluvii Testes.*" He strongly opposed Lhwyd's explanation of the origin of fossils, and referred these objects directly to the Flood. The most renowned work, however, of this time, was published at Zurich, in 1726, by Scheuchzer, a physician and naturalist, and professor in the University of Altorf. It bore the title "*Homo Diluvii Testis.*" The specimen upon which this work was based was found at Oeningen, and was regarded as the skeleton of a child destroyed by the Deluge. The author recognized in this remarkable fossil, not merely the skeleton, but also portions of the muscles, the liver, and the brain. The same

author was fortunate enough to discover, subsequently, near Altorf, two fossil vertebræ, which he at once referred to that "Accursed race destroyed by the Flood!" These, also, he carefully described and figured in his "*Physica Sacra*," published at Ulm in 1731. Engravings of both were subsequently given in the "Copper-Bible." Cuvier afterward examined these interesting relics, and pronounced the skeleton of the supposed child to be the remains of a gigantic Salamander, and the two vertebræ to be those of an Ichthyosaurus!

Another famous book appeared in Germany in the same year in which Scheuchzer's first volume was published. The author was John Bartholomew Adam Beringer, professor at the University of Würtzburg, and his great work[4] indirectly had an important influence upon the investigation of fossil remains. The history of the work is instructive, if only as an indication of the state of knowledge at that date. Professor Beringer, in accordance with views of his time, had taught his pupils that fossil remains, or "figured stones," as they were called, were mere "sports of nature." Some of his fun-loving students reasoned among themselves, "If Nature can make figured stones in sport, why cannot we?" Accordingly, from the soft limestone in the neighboring hills, they carved out figures of marvellous and fantastic forms, and buried them at the localities where the learned Professor was accustomed to dig for his fossil treasures. His delight at the discovery of these strange forms encouraged further production, and taxed the ingenuity of these youthful imitators of Nature's secret processes. At last Beringer had a large and unique collection of forms, new to him, and to science, which he determined to publish to the world. After long and patient study, his work appeared, in Latin, dedicated to the reigning prince of the country, and illustrated with twenty-one folio plates. Soon after the book was published, the deception practised upon the credulous Professor became known; and, in place of the glory he expected from his great undertaking, he received only ridicule and disgrace. He at once endeavored to repurchase and destroy the volumes already issued, and succeeded so far that few copies of the first

[4] *Lithographia Wirceburgensis, ducentis lapidum figuratorum, a potiori, insectiformium, prodigiosis imaginibus exornata.* Wirceburgi, 1726. Edit. II. Francofurti et Lipsiae. 1767.

edition remain. His small fortune, which had been seriously impaired in bringing out his grand work, was exhausted in the effort to regain what was already issued, as the price rapidly advanced in proportion as fewer copies remained; and, mortified at the failure of his life's work, he died in poverty. It is said that some of his family, dissatisfied with the misfortune brought upon them by this disgrace and the loss of their patrimony, used a remaining copy for the production of a second edition, which met with a large sale, sufficient to repair the previous loss, and restore the family fortune. This work of Beringer, in the end, exerted an excellent influence upon the dawning science of fossil remains. Observers became more cautious in announcing supposed discoveries, and careful study of natural objects gradually replaced vague hypotheses.

The above works, however, are hardly fair examples of the literature on fossils during this part of the eighteenth century. Scheuchzer had previously published his well-known "Complaint and Vindication of the Fishes," illustrated with good plates. Moro, in his work on "Marine Bodies which are found in the Mountains," 1740, showed the effects of volcanic action in elevating strata, and causing faults. Vallisneri had studied with care the marine deposits of Italy. Donati, in 1750, had investigated the Adriatic, and ascertained by soundings that shells and corals were being imbedded in the deposits there, just as they were found in the rocks.

John Gesner's dissertation, "*De Petrificatis*," published at Leyden in 1758, was a valuable contribution to the science. He enumerated the various kinds of fossils, and the different conditions in which they are found petrified, and stated that some of them, like those at Oeningen, resembled the shells, fishes, and plants of the neighboring region, while others, such as Ammonites and Belemnites, were either unknown species, or those found only in distant seas. He discusses the structure of the earth at length, and speculates as to the causes of changes in sea and land. He estimates that, at the observed rate of recession of the ocean, to allow the Apennines, whose summits are filled with marine shells, to reach their present height, would have taken about eighty thousand years, a period more than "ten times greater than the age of the universe." He accordingly refers the change to the

direct command of the Deity, as related by Moses, that "The waters should be gathered together in one place, and the dry land appear."

Voltaire (1694–1778), discussed geological questions and the nature of fossils in several of his works, but his published opinions are far from consistent. He ridiculed effectively and justly the cosmogonists of his day, and showed, also, that he knew the true nature of organic remains. Finding, however, that theologians used these objects to confirm the Scriptural account of the deluge, he changed his views, and accounted for fossil shells found in the Alps, by suggesting that they were Eastern species, dropped by the pilgrims on their return from the Holy Land!

Buffon, in 1749, published his important work on Natural History, and included in it his "Theory of the Earth," in which he discussed, with much ability, many points in Geology. Soon after the book was published, he received an official letter from the Faculty of Theology in Paris, stating that fourteen propositions in his works were reprehensible, and contrary to the creed of the church. The first objectionable proposition was as follows: "The waters of the sea have produced the mountains and valleys of the land,—the waters of the heavens reducing all to a level, will at last deliver the whole land over to the sea, and the sea successively prevailing over the land, will leave dry new continents like those we inhabit.

Buffon was politely requested by the college to recant, and having no particular desire to be a martyr to science, submitted the following declaration, which he was required to publish in his next work: "I declare that I had no intention to contradict the text of Scripture; that I believe most firmly all therein related about the creation, both as to order of time and matter of fact; and I abandon everything in my book respecting the formation of the earth, and, generally, all which may be contrary to the narration of Moses."

This single instance will suffice to indicate one great obstacle to the advancement of science, even up to the middle of the eighteenth century.

Another important work appeared in France about this time, Bourguet's "*Traité des Pétrifactions*," published in 1758, which is well illustrated with faithful plates. In England, a discourse on earthquakes, by Dr. Robert Hooke, was published in 1705. This

author held some views in advance of his time, and maintained that figured stones were "really the several bodies they represent or the moldings of them petrified, and not, as some have imagined, a *lusus naturæ*, sporting herself in the needless formation of useless things." He anticipates one important conclusion from fossils, when he states that "though it must be very difficult to read them and to raise a chronology out of them, and to state the intervals of time wherein such or such catastrophes and mutations have happened, yet it is not impossible." He also states that fossil turtles, and such large Ammonites as are found in Portland, seem to have been the productions of hotter countries, and hence it is necessary to suppose that England once lay under the sea within the torrid zone. He seems to have suspected that some of the fossils of England belonged to extinct species, but thought they might possibly be found living in the bottom of distant oceans.

Dr. Woodward's "Natural History of the Fossils of England" appeared in 1729. This work was based on a systematic collection of fossils which he had brought together, and which he subsequently bequeathed to the University of Cambridge, where it is still preserved, with his arrangement carefully retained. This descriptive part of this work is interesting, but his conclusions are made to coincide strictly with the Scriptural account of the creation and deluge. He had previously stated, in another work, that he believed, "the whole terrestrial globe to have been taken to pieces and dissolved at the flood, and the strata to have settled down from this promiscuous mass." In support of this view, he stated that, "Marine bodies are lodged in the strata according to the order of their gravity, the heavier shells in stones, the lighter in chalk, and so of the rest."[5]

The most important work on fossils published in Germany at this time, was that of George Wolfgang Knorr, which was continued after his death by Walch. This work consisted of four folio volumes, with many plates, and was printed at Nuremberg, 1755–73. A large number of fossils were accurately figured and described, and the work is one of permanent value.[6] A French translation of this work appeared in 1767–78. Burton's "*Orycto-graphie de Bruxelles*," 1784, contains figures and descriptions of fossils found in Belgium.

[5] Essay towards a Natural History of the Earth. 1695.

[6] *Lapides ex celeberr. viror. sententia diluvii universalis testes, quos in ordines ac species distribuit, suis coloribus expremit, etc.* 272 Tab. 1755–73.

Abraham Gottlieb Werner (1750–1817), Professor of Mineralogy at Freyberg, did much to advance the science of Geology, and indirectly, that of fossils. He first indicated the relations of the main formations to each other, and, according to his pupil, Professor Jameson, first made the highly important observation "that different formations can be discriminated by the petrifactions they contain." Morever, "that the petrifactions contained in the oldest rocks are very different from any of the species of the present time; that the newer the formation, the more do the remains approach in form to the organic beings of the present creation." Unfortunately, Werner published little, and his doctrines were mainly disseminated by his enthusiastic pupils.

The great contest between the Vulcanists and the Neptunists started at this time, mainly through Werner, whose doctrines led to the controversy. The comparative merits of fire and water, as agencies in the formation of certain rocks, were discussed with a heat and acrimony characteristic of the subject and the time. Werner believed in the aqueous theory, while the igneous theory was especially advocated by Hutton of Edinburgh, and his illustrator, Playfair. This discussion resulted in the advancement of descriptive geology, but the study of fossils gained little thereby.

The "*Protogæa*" of Leibnitz, the great mathematician, published in 1749, about thirty years after his death, was a work of much merit. This author supposed that the earth had gradually cooled from a state of igneous fusion, and was subsequently covered with water. The subsidence of the lower part of the earth, the deposits of sedimentary strata from inundations, and their induration, as well as other changes, followed. All this, he supposed to have been accomplished in a period of six natural days. In the same work Leibnitz shows that he had examined fossils with considerable care.

Linnæus (1707–1778), the famous Swedish botanist, and the founder of the modern system of nomenclature in Natural History, confined his attention almost entirely to the living forms. Although he was familiar with the literature of fossil remains, and had collected them himself, he did not include them in his system of plants and animals, but kept them separate, with the minerals; hence he did little directly to advance this branch of science.

During the last quarter of the eighteenth century, the belief that

fossil remains were deposited by the Deluge sensibly declined, and the dawn of a new era gradually appeared. Let us pause for a moment here, and see what real progress had been made; what foundation had been laid on which to establish a science of fossil remains.

The true nature of these objects had now been clearly determined. They were the remains of animals and plants. Most of them certainly were not the relics of the Mosaic Deluge, but had been deposited long before, part in fresh water and part in the sea. Some indicated a mild climate, and some the tropics. That any of these were extinct species, was as yet only suspected. Large collections of fossils had now been made, and valuable catalogues, well illustrated, had been published. Something was known, too, of the geological position of fossils. Steno, long before, had observed that the lowest rocks were without life. Lehmann had shown that above these primitive rocks, and derived from them, were the secondary strata, full of the records of life; and above these were alluvial deposits, which he referred to local floods, and the Deluge of Noah. Rouelle, Fuchsel, and Odoardi had shed new light on this subject. Werner had distinguished the transition rocks, containing fossil remains, between the primitive and the secondary, while everything above the chalk he grouped together, as the "overflowed land." Werner, as we have seen, had done more than this, if we give him the credit his pupils claim for him. He had found that the formations he examined contained each its own peculiar fossils, and that from the older to the newer there was a gradual approach to recent forms. William Smith had worked out the same thing in England, and should equally divide the honor of this important discovery.

The greatest advance, however, up to this time, was that men now preferred to *observe*, rather than to *believe*, and facts were held in greater esteem than vague speculations. With this preparation for future progress, the second period in the history of Palæontology, as I have divided it, may appropriately be considered at an end.

Thus far, I have said nothing in regard to one branch of my subject, the *methods* of Palæontological research, for up to this time, of method there was none. We have seen that those of the ancients who noticed marine shells in the solid rock, called them

such, and concluded that they had been left there by the sea. The discovery of fossils led directly to theories of how the earth was formed. Here the progress was slow. Subterranean spirits were supposed to guard faithfully the mysteries of the earth; while above the earth, Authority guarded with still greater power the secrets men in advance of their age sought to know. The dominant idea of the first sixteen centuries of the present era was, that the universe was made for Man. This was the great obstacle to the correct determination of the position of the earth in the universe, and, later, of the age of the earth. The contest of Astronomy against authority was long and severe, but the victory was at last with science. The contest of Geology against the same power followed, and continued almost to our day. The result is still the same. In the early stages of this contest, there was no strife, for science was benumbed by the embrace of superstition and creed, and little could be done till that was cast off. In a superstitious age, when every natural event is referred to a supernatural cause, science cannot live; and often as the sacred fire may be kindled by courageous far-seeing souls, will it be quenched by the dense mists of ignorance around it. Scarcely less fatal to the growth of science is the age of Authority, as the past proves too well. With freedom of thought, came definite knowledge, and certain progress; —but two thousand years was long to wait.

With the opening of the present century, began a new era in Palæontology, which we may here distinguish as the third period in its history. This branch of knowledge became now a science. Method replaced disorder, and systematic study superseded casual observation. For the next half century the advance was continuous, and rapid. One characteristic of this period was, *the accurate determination of fossils by comparison with living forms.* This will separate it from the two former epochs. Another distinctive feature of this period was the general belief that, *every species, recent and extinct, was a separate creation.*

At the very beginning of the epoch we are now to consider, three names stand out in bold relief: Cuvier, Lamarck, and William Smith. To these men, the science of Palæontology owes its origin. Cuvier and Lamarck, in France, had all the power which great talent, education, and station could give; William Smith, an English surveyor, was without culture or influence. The last years

of the eighteenth century had been spent by each of these men in preparation for his chosen work, and the results were now given to the world. Cuvier laid the foundation of the palæontology of Vertebrate animals; Lamarck, of the Invertebrates; and Smith established the principles of Stratigraphical Palæontology. The investigator of fossils to-day seldom needs to consult earlier authors of the science.

George Cuvier (1769–1832), the most famous naturalist of his time, was led to the study of extinct animals by ascertaining that the remains of fossil elephants he examined were extinct species. "This idea," he says later, "which I announced to the Institute in the month of January 1796, opened to me views entirely new respecting the theory of the earth, and determined me to devote myself to the long researches and to the assiduous labors which have now occupied me for twenty-five years."[7]

It is interesting to note here that in this first investigation of fossil vertebrates, Cuvier employed the same method that gave him such important results in his later researches. Remains of elephants had been known to Europe for centuries, and many authors, from Pliny down to the contemporaries of Cuvier, had written about them. Some had regarded the bones as those of human giants, and those who recognized what they were considered them remains of the elephants imported by Hannibal or the Romans. Cuvier, however, compared the fossils directly with the bones of existing elephants, and proved them to be distinct. The fact that these remains belonged to extinct species was of great importance. In the case of fossil shells, it was difficult to say that any particular form was not living in a distant ocean; but the two species of existing elephants, the Indian and the African, were well known, and there was hardly a possibility that another living one would be found.

It is important to bear in mind, too, that Cuvier's preparation for the study of the remains of animals was far in advance of any of his predecessors. He had devoted himself for years to careful dissections in the various classes of the animal kingdom, and was really the founder of comparative anatomy, as we now understand it. Cuvier investigated the different groups of the whole kingdom with care, and proposed a new classification founded on the plan of structure, which in its main features is the one in use to-day.

[7] *Ossemens Fossiles*, Second Edition, Vol. I, p. 178.

The first volume of his Comparative Anatomy appeared in 1800, and the work was completed in five volumes in 1805.

Previous to Cuvier, the only general catalogue of animals was contained in Linnæus' "*Systema Naturæ.*" In this work, as we have seen, fossil remains were placed with the Minerals, not in their appropriate places among the animals and plants. Cuvier enriched the animal kingdom by the introduction of fossil forms among the living, bringing all together into one comprehensive system. His great work, "*Le Règne Animal,*" appeared in four volumes, in 1817, and with its two subsequent editions remains the foundation of modern zoology. Cuvier's classic work on vertebrate fossils—"*Recherches sur les Ossemens Fossiles,*" in four volumes, appeared in 1812–13. Of this work, it is but just to say that it could only have been written by a man of genius, profound knowledge, the greatest industry, and with the most favorable opportunities.

The introduction to this work was the famous "Discourse on the Revolutions of the Surface of the Globe," which has perhaps been as widely read as any other scientific essay. The discovery of fossil bones in the gypsum quarries of Paris, by the workmen, who considered them human remains; the careful study of these relics by Cuvier, and his restorations from them of strange beasts that had lived long before, is a story with which you are all familiar. Cuvier was the first to prove that the earth had been inhabited by a succession of different series of animals, and he believed that those of each period were peculiar to the age in which they lived.

In looking over his work after a lapse of three-quarters of a century, we can now see that Cuvier was wrong on some important points, and failed to realize the direction in which science was rapidly tending. With all his knowledge of the earth, he could not free himself from tradition, and believed in the universality and power of the Mosaic deluge. Again, he refused to admit the evidence brought forward by his distinguished colleagues against the permanence of species, and used all his great influence to crush out the doctrine of evolution, then first proposed. Cuvier's definition of a species, the dominant one for half a century, was as follows: "A species comprehends all the individuals which descend from each other, or from a common parentage, and those which resemble them as much as they do each other."

The law of "Correlation of Structures," as laid down by Cuvier, has been more widely accepted than almost any thing else that bears his name; and yet, although founded in truth, and useful within certain limits, it would certainly lead to serious error if applied widely in the way he proposed.

In his Discourse, he sums this law as follows: "A claw, a shoulder blade, a condyle, a leg or arm bone, or any other bone separately considered, enables us to discover the description of teeth to which they have belonged; so also reciprocally we may determine the form of the other bones from the teeth. Thus, comencing our investigation by a careful survey of any one bone by itself, a person who is sufficiently master of the laws of organic structure, may, as it were, reconstruct the whole animal to which that bone had belonged."

We know to-day that unknown extinct animals cannot be restored from a single tooth or claw, unless they are very similar to forms already known. Had Cuvier, himself, applied his methods to many forms from the early Tertiary or older formations, he would have failed. If, for instance, he had had before him the disconnected fragments of an Eocene Tillodont, he would undoubtedly have referred a molar tooth to one of his Pachyderms; an incisor tooth to a Rodent; and a claw bone to a Carnivore. The tooth of a Hesperornis would have given him no possible hint of the rest of the skeleton, nor its swimming feet the slightest clue to the ostrich-like sternum or skull. And yet, the earnest belief in his own methods led Cuvier to some of his most important discoveries.

Jean Lamarck (1744–1829), the philosopher and naturalist, a colleague of Cuvier, was a learned botanist before he became a zoologist. His researches on the invertebrate fossils of the Paris Basin, although less striking, were not less important than those of Cuvier on the vertebrates; while the conclusions he derived from them form the basis of modern biology. Lamarck's method of investigation was the same, essentially, as that used by Cuvier, namely: a direct comparison of fossils with living forms. In this way, he soon ascertained that the fossil shells imbedded in the strata beneath Paris were, many of them, extinct species, and those of different strata differed from each other. His first memoir on this subject appeared in 1802,[8] and, with his later works,

[8] *Mémoires sur les fossiles des environs de Paris*. 1802–6.

effected a revolution in conchology. His "System of Invertebrate Animals" appeared the year before, and his famous "*Philosophie Zoologique*," in 1809. In these two works, Lamarck first announced the principles of Evolution. In the first volume of his "Natural History of Invertebrate Animals,"[9] he gave his theory in detail; and to-day one can only read with astonishment his far-reaching anticipations of modern science. These views were strongly supported by Geoffroy Saint-Hilaire, but bitterly opposed by Cuvier; and their great contest on this subject is well known.

In looking back from this point of view, the philosophical breadth of Lamarck's conclusions, in comparison with those of Cuvier, is clearly evident. The invertebrates on which Lamarck worked offered less striking evidence of change than the various animals investigated by Cuvier; yet they led Lamarck directly to Evolution, while Cuvier ignored what was before him on this point, and rejected the proof offered by others. Both pursued the same methods, and had an abundance of material on which to work, yet the facts observed induced Cuvier to believe in catastrophes; and Lamarck, in the uniform course of nature. Cuvier declared species to be permanent; Lamarck, that they were descended from others. Both men stand in the first rank in science; but Lamarck was the prophetic genius, half a century in advance of his time.

While the Paris Basin was yielding such important results for Palæontology, its geological structure was being worked out with great care. The results appeared in a volume by Cuvier and Alex. Brongniart, chiefly the work of the latter, published in 1808.[10] This was the first systematic investigation of Tertiary strata. Three years later, the work was issued in a more extended form. The separate formations were here carefully distinguished by their fossils, the true importance of which for this purpose was distinctly recognized. This advance was not accepted without some opposition, and it is an interesting fact that Jameson, who claimed for Werner the theory here put in practice, rejected its application, and wrote as follows: "To Cuvier and Brongniart we are indebted for much valuable information in their description of the country around Paris, but we must protest against the use they have made

[9] *Histoire naturelle des animaux sans vertèbres.* 7 vols. Paris, 1815–1822. 2d edition. 11 vols. 1835–1845.

[10] *Essai sur la Géographie Mineralogique des environs de Paris.* 4to, 1808.

of fossil organic remains in their geognostical descriptions and investigations."[11]

William Smith (1769–1839), "the father of English Geology," had previously published a "Tabular View of the British Strata." He appears to have arrived independently at essentially the same view as Werner in regard to the relative position of stratified rocks. He had determined that the order of succession was constant, and that the different formations might be identified at distant points by the fossils they contained. In his later works, "Strata identified by Organized Fossils," published in 1816–20, and "Stratigraphical System of Organized Fossils," 1817, he gave to the world results of many years of careful investigations on the Secondary formations of England. In the latter work, he speaks of the success of his method in determining strata by their fossils, as follows: "My original method of tracing the strata by the organized fossils imbedded therein, is thus reduced to a science not difficult to learn. Ever since the first written account of this discovery was circulated in 1799, it has been closely investigated by my scientific acquaintances in the vicinity of Bath, some of whom search the quarries of different Strata in that district, with as much certainty of finding the characteristic Fossils of the respective rocks, as if they were on the shelves of their cabinets."

The systematic study of fossils now attracted attention in England, also, and was prosecuted with considerable zeal, although with less important results than in France. An extensive work on this subject, by James Parkinson, entitled "Organic Remains of a Former World," was begun in 1804, and completed in three volumes in 1811. A second edition appeared in 1833. This work was far in advance of previous publications in England, and, being well illustrated, did much to make the collection and study of fossils popular. The belief in the geological effects of the Deluge had not yet lost its power, although restricted now to the later deposits; for Parkinson in his later edition wrote as follows: "Why the earth was at first so constituted that the deluge should be rendered necessary — why the earth could not have been at first stored with all those substances, and endued with all those properties which seemed to have proceeded from the deluge — why so many beings were created, as it appears, for the purpose of being destroyed — are questions which I presume not to answer."

[11] Translation of Cuvier's Discourse. Note K. (B.), p. 103, 1817.

William Buckland (1784–1856), published in 1823 his celebrated "*Reliquiæ Diluvianæ*," in which he gave the results of his own observations in regard to the animal remains found in the caves, fissures and alluvial gravels of England. The facts presented are of great value, and the work was long a model for similar researches. Buckland's conclusions were, that none of the human remains discovered in the caves were as old as the extinct mammals found with them, and that the Deluge was universal. In speaking of fossil bones found in the Himalaya mountains, he says: "The occurrence of these bones at such an enormous elevation in the region of eternal snow, and consequently in a spot now unfrequented by such animals as the horse and deer, can, I think, be explained only by supposing them to be of antediluvian origin, and that the carcasses of the animals were drifted to their present place, and lodged in sand, by the diluvial waters."

The foundation of the "Geological Society of London," in 1807, marks an important point in the history of palæontology. To carefully collect materials for future generalizations, was the object in view, and this organization gradually became the centre in Great Britain for those interested in geological science. The society was incorporated in 1826, and has since been the leading organization in Europe for the advancement of the sciences within its field. The Geological Society of France, established at Paris in 1832, and the German Geological Society, founded at Berlin in 1848, have likewise contributed largely to geological investigations in these countries, and to some extent in other parts of the world. In the publications of these three societies, the student of Palæontology will find a mine of valuable materials for his work.

The systematic study of fossil Plants may be said to date from the publication of Adolphe Brongniart's "*Prodrome*," in 1828.[12] This was very soon followed by his larger work, "*Histoire des végétaux fossiles*," issued in 1828–48. Brongniart pursued the same method as Cuvier and Lamarck, viz.: the comparison of fossils with living forms, and his results were of great importance. In his "*Tableau des genres végétaux fossiles*," etc., published in Paris in 1849, he gives the classification and distribution of the genera of fossil plants, and traces out the historical progression of vegetable life on the globe, as he had done to a great extent in his

[12] *Prodrome d'une histoire des végétaux fossiles.* 8vo. Paris, 1828.

previous works. He shows that the cryptogamic forms prevailed in the primary formations; the conifers and cycads in the secondary, and the higher forms in the Tertiary, while four-fifths of living plants are exogens.

In England, Lindley and Hutton published, in 1831–37, a valuable work in three volumes, entitled, "Fossil Flora of Great Britain." This work was illustrated by many accurate plates, in which the plants of the coal formation were especially represented. Henry Witham also published two works in 1831 and 1833, in which he treated especially of the internal structure of fossil plants. "Antediluvian Phytology," by Artis, was published in London in 1838. Bowerbank's "History of the Fossil Fruits and Seeds of the London Clay," appeared in 1843. Hooker's memoir "On the Vegetation of the Carboniferous Period as compared with that of the present day," published in 1848, was an important contribution to the science. Bunbury, Williamson, and others, also published various papers on fossil plants. This branch of Palæontology, however, attracted much less attention in England, than on the Continent.

In Germany, the study of fossil plants dates back to the beginning of the century. Von Schlotheim, a pupil of Werner, published in 1804 an illustrated volume on this subject. A more important work was that of Count Sternberg, issued in 1820–38, and illustrated with excellent plates. Cotta in 1832 published a book with the title "*Die Dendrolithen*," in which he gave the results of his investigations on the inner structure of fossil plants. Von Gutbier in 1835, and Germar in 1844–53, described and figured the plants of two important localities in Germany. Corda's "*Beiträge zur Flora der Vorwelt*," issued at Prague, in 1845, was essentially a continuation of the work of Sternberg. Unger's "*Chloris protogœa*," 1841–45, "*Genera et species plantarum fossilium*," 1850, and his larger work published in 1852, are all standard authorities. In the latter, the theory of descent is applied to the vegetable world. Schimper and Mougeot's "Monograph on the fossil plants of the Vosges," 1845, was well illustrated, and contained noteworthy results.

Göppert, in 1836, published a valuable memoir entitled, "*Systema Filicum Fossilium*," in which he made known the results of his study of fossil ferns. In the same year, this botanist began a series of experiments, in which he attempted to imitate the process

of fossilization, as found in nature. He steeped various animal and vegetable substances in waters holding, some calcareous, others siliceous, and others metallic matter in solution. After a slow saturation, the substances were dried, and exposed to heat until the organic matters were burned. In this way Göppert successfully imitated various processes of petrifcation, and explained many things in regard to fossils that had previously been in question. His discovery of the remains of plants throughout the interior of coal did much to clear up the doubts about the formation of that substance. In 1841, Göppert published an important work in which he compared the genera of fossil plants with those now living. In 1852, another extensive work by this author appeared, entitled, "*Fossile Flora des Uebergangs-Gebirges.*"

Andræ, Braun, Dunker, Ettinsghausen, Geinitz, and Goldenberg, all made notable contributions to fossil Botany in Germany, during the period we are now considering.

The systematic study of invertebrate fossils, so admirably begun by Lamarck, was continued actively in France. The Tertiary shells of the Seine valley were further investigated by Defrance, and especially by Deshayes, whose great work on this subject was begun in 1824.[13] DesMoulin's essay on *Sphérulites* in 1826, Blainville's memoir on *Belemnites* in 1827, Férussac's various memoirs on land and fresh water fossil shells, were valuable additions to the subject. A later work of great importance was D'Orbigny's *Paléontologie Française*, 1840–44, which described the mollusca and radiates in detail, according to formations. The other publications of this author are both numerous and valuable. Brongniart and Desmarest's "*Histoire naturelle des Crustacés Fossiles,*" published in 1822, is a pioneer work on this subject. Michelin's memoir on the fossil corals of France, 1841–46, was another important contribution to palæontology. Agassiz's works on fossil Echinoderms and Mollusks are valuable contributions to the science. The works of d'Archiac, Coquand, Cotteau, Desor, Edwards, Haime, and De Verneuil, are likewise of permanent value.

In Italy, Bellardi, Merian, Michellotti, Phillipi, Zingo, and others, contributed important results to Palæontology.

In Belgium, Bosquet, Nyst, Koninck, Ryckholt, Van Beneden,

[13] *Description des coquilles fossiles des environs de Paris.* 3 vols. Paris, 1824-37.

and others, have all aided materially in the progress of the science.

In England, also, invertebrate fossils were studied with care, and continued progress was made. Sowerby's "Mineral Conchology of Great Britain," in six volumes, a systematic work of great value, was published in 1812–30, and soon after was translated into French and German. Its figures of fossil shells are excellent, and it is still a standard work. Miller's "Natural History of the Crinoidea," published at Bristol, in 1821, and Austin's later monograph, are valuable for reference. Brown's "Fossil Conchology of Britain and Ireland" appeared in 1839, and Brodie's History of the Fossil Insects of England, in 1845. Phillips' illustration of the geology of Yorkshire, 1829–36, and his work on the Palæozoic fossils of Cornwall, Devonshire, and West Somerset, 1843, contained a great deal of original matter in regard to fossil remains. Morris' "Catalogue of British Fossils," issued in 1843, and the later edition in 1854, is most useful to the working palæontologist. The memoirs of Davidson on the Brachiopoda, Edwards, Forbes, Morris, Lycett, Sharpe, and Wood on other Mollusca, Wright on the Echinoderms, Salter on Crustacea, Busk on Polyzoa, Jones on the Entomostraca, and Duncan and Lonsdale on Corals, are of especial value. King's volume on Permian fossils, Mantell's various memoirs, Dixon's work on the fossils of Sussex, 1850, and McCoy's works on Palæozoic fossils, all deserve honorable mention. Sedgwick, Murchison, and Lyell, although their greatest services were in systematic geology, each contributed important results to the kindred science of palæontology during the period we are reviewing.

In Germany, Schlotheim's treatise, "*Die Petrifactenkunde*," published at Gotha in 1820, did much to promote a general interest in fossils. By far the most important work issued on this subject was the "*Petrifacta Germanica*," by Goldfuss, in three folio volumes, 1826 to 1844, which has lost little of its value. Bronn's "*Geschichte der Natur*," 1841–46, was a work of great labor, and one of the most useful in the literature of this period. The author gave a list of all the known fossil species, with full references, and also their distribution through the various formations. This gave exact data on which to base generalizations, hitherto of comparatively little value.

Among other early works of interest in this department may be

mentioned, Dalman's memoir on *Trilobites*, 1828, and Burmeister's on the same subject, 1843. Giebel's well known "*Fauna der Vorwelt*," 1847–1856, gave lists of all the fossils described up to that time, and hence is a very useful work. The "*Lethæa Geognostica*" by Bronn, 1834–38, and the second edition by Bronn and Roemer, 1846–56, is a comprehensive general treatise on Palæontology, and the most valuable work of the kind yet published.

The researches of Ehrenberg, in regard to the lowest forms of animals and plants, threw much light on various points in Palæontology, and showed the origin of extensive deposits, the nature of which had before been in doubt. Von Buch, Barrande, Beyrich, Berendt, Dunker, Geinitz, Heer, Hörnes, Klipstein, Von Münster, Reuss, Roemer, Sandberger, Suess, Von Hagenow, Von Hauer, Zeiten, and many others, all aided in the advancement of this branch of science. Angelin, Hisinger, and Nilsson, in Scandinavia; Abich, DeWaldheim, Eichwald, Keyserling, Kutorga, Nordmann, Pander, Rouillier, and Volborth, in Russia; and Pusch in Poland, published important results on fossil invertebrates.

The impetus given by Cuvier to the study of vertebrate fossils extended over Europe, and great efforts were made to continue discoveries in the direction he had so admirably pointed out.

Louis Agassiz (1807–73), a pupil of Cuvier, and long an honored member of this association, attained eminence in the study of ancient as well as of recent life. His great work on Fossil Fishes[14] deserves to rank next to Cuvier's "*Ossemens Fossiles.*" The latter contained mainly fossil mammals and reptiles, while the fishes were left without a historian till Agassiz began his investigations. His studies had admirably fitted him for the task, and his industry brought together a vast array of facts bearing on the subject. The value of this grand work consists not only in its faithful descriptions and plates, but also in the more profound results it contained. Agassiz first showed that there is a correspondence between the succession of fishes in the rocks, and their embryonal development. This is now thought to be one of the strongest points in favor of evolution, although its discoverer interpreted the facts as bearing the other way.

Pander's memoirs on the fossil fishes of Russia form a worthy supplement to Agassiz's classic work. Brandt's publications are

[14] *Recherches sur les Poissons fossiles*, 1833–45.

likewise of great value; and those of Lund, in Sweden, have an especial interest to Americans, in consequence of his researches in the caves of Brazil.

Croizet and Jobert's "*Recherches sur les ossemens fossiles du département du Puy-de-Dôme*," published in 1828, contained valuable results in regard to fossil mammals. Geoffroy St. Hilaire's researches on fossil Reptiles, published in 1831, were an important advance. De Serres and De Christol's explorations in the caverns in the South of France, published between 1829 and 1839, were of much value. Schmerling's researches in the caverns of Belgium, published in 1833–36, were especially important on account of the discovery of human remains mingled with those of extinct animals. Deslongchamp's memoirs on fossil reptiles, 1835, are still of great interest. Pictet's general treatise on palæontology was a valuable addition to the literature, and has done much to encourage the study of fossils.[15] DeBlainville, in his grand work, "*Ostéographie*," issued in 1839–56, brought together the remains of living and extinct vertebrates, forming a series of the greatest value for study. Aymard and Pomel's contributions to vertebrate Palæontology are both of value. Gervais and Lartet added much to our knowledge of the subject, and Bravard and Hébert's memoirs are well known.

The brilliant discoveries of Cuvier in the Paris Basin, excited great interest in England, and when it was found that the same Tertiary strata existed in the south of England, careful search was made for vertebrate fossils. Remains of some of the same genera described by Cuvier were soon discovered, and other extinct animals new to science were found in various parts of the kingdom. König, to whom we owe the name *Ichthyosaurus*, and Conybeare, who gave the generic designation *Plesiosaurus*, and also *Mosasaurus*, were among the earliest writers in England on fossil reptiles. The discovery of these three extinct types, and the discussion as to their nature, forms a most interesting chapter in the annals of Palæontology. The discovery of the *Iguanodon*, by Mantell, and the *Megalosaurus*, by Buckland, excited still higher interest. These great reptiles differed much more widely from living forms than the mammals described by Cuvier, and the period in which they lived soon became known as the "age of

[15] "*Traité élémentaire de paléontologie*," etc., *Genève*. 4 vols. 1844–46. Second Edition. Paris, 1853–55.

Reptiles." The subsequent researches of these authors added largely to the existing knowledge of various extinct forms, and their writings did much to arouse public interest in the subject.

Richard Owen, a pupil of Cuvier, followed, and brought to bear upon the subject an extensive knowledge of comparative anatomy, and a wide acquaintance with existing forms. His contributions have enriched almost every department of palæontology, and of extinct vertebrates especially, he has been, since Cuvier, the chief historian. The fossil reptiles of England, he has systematically described, as well as those of South Africa. The extinct Struthious birds of New Zealand, he has made known to science, and accurately described in extended memoirs. His researches on the fossil mammals of Great Britain, the extinct Edentates of South America, and the ancient Marsupials of Australia, each forms an important chapter in the history of our science.

The personal researches of Falconer and Cautley in the Sewalik Hills of India brought to light a marvellous vertebrate fauna of Pliocene age. The remains thus secured were made known in their great work, "*Fauna Antiqua Sivalensis*," published at London in 1845. The important contributions of Egerton to our knowledge of fossil fishes, and Jardine's well known work, "Ichnology of Annandale," also belong to this period.

The study of vertebrate fossils in Germany was prosecuted with much success during the present period. Blumenbach, the ethnologist, in several publications between 1803 and 1814, recorded valuable observations on this subject. In 1812, Sömmerring gave an excellent figure of a pterodactyle, which he named and described. Goldfuss' researches on the fossil vertebrates from the Caves of Germany, published in 1820–23, made known the more important facts of that interesting fauna. His later publications on extinct Amphibians and Reptiles were also noteworthy. Jäger's investigations on the extinct vertebrate fauna of Wurtemberg, published between 1824 and 1839, were an important advance. To Plieninger's researches in the same region, 1834–44, we owe the discovery of the first Triassic mammal (*Microlestes*), as well as important information in regard to Labyrinthodonts. Kaup's researches on fossil mammals, 1832–41, brought to light many interesting forms, and to him we are indebted for the generic name *Dinotherium*, and excellent descriptions of the remains then known.

Count Münster's "*Beiträge zur Petrifacten-Kunde*," published 1843–46, contained several valuable papers on fossil vertebrates; and the separate papers by the same author are of interest. Andreas Wagner wrote on Pterosaurians in 1837, and later gave the first description of fossil mammals of the Tertiary of Greece, 1837–40. Johannes Müller published an important illustrated work on Zeuglodonts, in 1849, and various notable memoirs; and Quenstedt, interesting descriptions of fossil reptiles, as well as other papers of much value. Rütimeyer's suggestive memoirs are widely known.

Hermann von Meyer's contributions to vertebrate palæontology are by far the most important published in Germany during the period we are now considering. From 1830, his investigations on this subject were continuous for nearly forty years, and his various publications are all of value. His "*Beiträge zur Petrifactenkunde*," 1831–33, contains a series of valuable memoirs. His "*Palæologica*," issued in 1832, includes a synopsis of the fossil vertebrates then known, with much original matter. His great work, "*Zur Fauna der Vorwelt*," 1845–60, includes a series of monographs invaluable to the student of vertebrate palæontology. This work, as well as his other chief publications, was illustrated with admirable plates from his own drawings. Other memoirs by this author will be found in the "*Palæontographica*," of which he was one of the editors. In the many volumes of this publication, which began in 1851, and is still continued, will be found much to interest the investigator in any branch of palæontology.

The "Palæontographical Society of London," established in 1847, has also issued a series of volumes containing valuable memoirs in various branches of Palæontology. These two publications together are a storehouse of knowledge in regard to extinct forms of animal and vegetable life.

It may be interesting here to note briefly the use of general terms in Palæontology, as the gradual progress of the science was indicated to some extent in its terminology. At first, and for a long time, the name "*fossil*" was appropriately used for objects dug from the earth, both minerals and organic remains. The term "Oryctology," having essentially the same meaning, was also used for this branch of study. For a long period, too, the termination *ites* (λίθος, a stone) was applied to fossils to distinguish them from

the corresponding living forms; as, for instance, "*Ostracites*," used by Pliny. At a later date, the general name "figured stones" (*lapides figurati*) was extensively used; and less frequently, "Deluge stones" (*lapides diluviani*). The term "organized fossils" was used to distinguish fossils from minerals, when the real difference became known, although "*Reliquiæ*" was sometimes employed. The term "petrifactions" (*Petrificata*) was defined by John Gesner in his work on fossils is 1758, and was afterwards extensively used. Palæontology is comparatively a modern term, having come into use only within the last half century. It was introduced about 1830, and soon was generally adopted in France and England; but in Germany it met with less favor, though used to some extent.

It would be interesting, too, did time permit, to trace the various opinions and superstitions, held at different times, in regard to some of the more common fossils, for example, the Ammonite, or the Belemnite. Of their supposed celestial origin; of their use as medicine by the ancients, and in the East to-day; of their marvellous power as charms, among the Romans, and still among the American Indians. It would be instructive, also, to compare the various views expressed by students in science, concerning some of the stranger extinct forms, for instance, the Nummulites, among Protozoa; the Rudistes, among Mollusks; or the Mosasaurus, among Reptiles. Dissimilar as such views were, they indicate in many cases gropings after truth,—natural steps in the increase of knowledge.

The third period in the history of Palæontology, which, as I have said, began with Cuvier and Lamarck at the beginning of the present century, forms a natural epoch extending through six decades. The definite characteristics of this period, as stated, were dominant during all this time, and the progress of Palæontology was commensurate with that of intelligence and culture.

For the first half of this period, the marvellous discoveries in the Paris Basin excited astonishment, and absorbed attention; but the real significance and value of the facts made known by Cuvier, Lamarck, and William Smith, were not appreciated. There was still a strong tendency to regard fossils merely as interesting objects of natural history, as in the previous period, and not as the key to profounder problems in the earth's history. Many prominent

geologists were still endeavoring to identify formations in different countries by their mineral characters, rather than by the fossils imbedded in them. Such names as "Old Red Sandstone," and "New Red Sandstone," were given in accordance with this opinion. Humboldt, for example, attempted to compare the formations of South America and Europe by their mineral features, and doubted the value of fossils for this purpose. In 1823, he wrote as follows: "Are we justified in concluding that all formations are characterized by particular species? that the fossil shells of the chalk, the muschelkalk, the Jura limestone, and the Alpine limestones, are all different? I think this would be pushing the induction much too far."[16] Jameson still thought minerals more important than fossils for characterizing formations; while Bakewell, later yet, defines Palæontology as comprising "Fossil Zoology and Fossil Botany, a knowledge of which may appear to the student as having little connection with Geology."

During the later half of the third period, greater progress was made, and before its close Geology was thoroughly established as a science. Let us consider for a moment what had really been accomplished up to this time.

It had now been proved beyond question that portions at least of the Earth's surface had been covered many times by the sea, with alternations of fresh water and of land; that the strata thus deposited were formed in succession, the lowest of the series being the oldest; that a distinct succession of animals and plants had inhabited the earth during the different geological periods; and that the order of succession found in one part of the earth was essentially the same in all. More than 30,000 new species of extinct animals and plants had now been described. It had been found, too, that from the oldest formations to the most recent, there had been an advance in the grade of life, both animal and vegetable, the oldest forms being among the simplest, and the higher forms successively making their appearance.

It had now become clearly evident, moreover, that the fossils from the older formations were all extinct species, and that only in the most recent deposits were there remains of forms still living. The equally important fact had been established, that in several groups of both animals and plants, the extinct forms were vastly more numerous than the living; while several orders of fossil

[16] *Essai géognôstique sur le gisement des Roches*, p. 41.

animals had no representatives in modern times. Human remains had been found mingled with those of extinct animals, but the association was regarded as an accidental one by the authorities in science; and the very recent appearance of Man on the earth was not seriously questioned. Another important conclusion reached, mainly through the labors of Lyell, was, that the earth had not been subjected in the past to sudden and violent revolutions; but the great changes wrought had been gradual, differing in no essential respect from those still in progress. Strangely enough, the corollary to this proposition, that Life, too, had been continuous on the earth, formed at that date no part of the common stock of knowledge.

In the physical world, the great law of "Correlation of forces" had been announced, and widely accepted; but in the organic world, the dogma of the miraculous creation of each separate species still held sway, almost as completely as when Linnæus declared: "There are as many different species as there were different forms created in the beginning by the Infinite Being." But the dawn of a new era was already breaking, and the third period of palæontology we may consider now at an end.

Just twenty years ago, science had reached a point when the belief in "special creations" was undermined by well established facts, slowly accumulated. The time was ripe. Many naturalists were working at the problem, convinced that Evolution was the key to the present and the past. But how had Nature brought this change about? While others pondered, Darwin spoke the magic word — "*Natural Selection*," and a new epoch in science began.

The fourth period in the history of Palæontology dates from this time, and is the period of to-day. One of the main characteristics of this epoch is the belief that *all life, living and extinct, has been evolved from simple forms.* Another prominent feature is the accepted fact of *the great antiquity of the human race.* These are quite sufficient to distinguish this period sharply from those that preceded it.

The publication of Charles Darwin's work on the "Origin of Species," November, 1859, at once aroused attention, and started a revolution which has already in the short space of two decades changed the whole course of scientific thought. The theory of

"Natural Selection," or as Spencer has happily termed it, the "Survival of the Fittest," had been worked out independently by Wallace, who justly shares the honor of the discovery. We have seen that the theory of Evolution was proposed and advocated by Lamarck, but he was before his time. The anonymous author of the "Vestiges of Creation," which appeared in 1844, advocated a somewhat similar theory which attracted much attention, but the belief that species were immutable was not sensibly affected until Darwin's work appeared.

The difference between Lamarck and Darwin is essentially this: Lamarck proposed the theory of Evolution; Darwin changed this into a doctrine, which is now guiding the investigations in all departments of biology. Lamarck failed to realize the importance of time and the interaction of life on life. Darwin, by combining these influences with those also suggested by Lamarck, has shown *how* the existing forms on the earth may have been derived from those of the past.

This revolution has influenced Palæontology as extensively as any other department of science, and hence the new period we are discussing. In the last epoch, species were represented independently, by parallel lines; in the present period, they are indicated by dependent, branching lines. The former was the analytic, the latter is the synthetic, period. To-day, the animals and plants [illegible] are believed to be genetically connected with those of [illegible]; and the palæontologist no longer deems species of [illegible] importance, but seeks for relationships and genealogies, [illegible] present with the present. Working in this spirit, and [illegible] method, the advance during the last decade has been [illegible] an earnest of what is yet to come.

[illegible] of palæontology in Great Britain during the pres- [illegible] been great, and the general interest in the science [illegible]. The views of Darwin soon found acceptance [illegible] his discovery of "Natural Selection," Darwin was [illegible] so able and bold an expounder as Huxley; [illegible] of the first to adopt his theory, and give it a vigor- [illegible] Huxley's masterly researches have been of great [illegible] departments of Biology, and his contributions to [illegible] invaluable. Among the latter, his original in- [illegible] on the relations of Birds and Reptiles are especially

noteworthy. His various memoirs on extinct Reptiles, Amphibians and Fishes, belong to the permanent literature of the subject. The important researches of Owen on the fossil vertebrates have been continued to the present time. He has added largely to his previous publications on the British fossil Reptiles, Birds, and Mammals; the extinct reptiles of South Africa, and the Post-Tertiary birds of New Zealand. His description of the *Archæopteryx* near the beginning of the period was a most welcome contribution.

The investigations of Egerton on Fossil Fishes have likewise been continued with important results. Busk, Dawkins, Flower, and Sanford have made valuable contributions to the history of fossil Mammals. Bell, Günther, Hulke, Lankester, Newton, Powrie, Miall, Traquair, and Seely, have made notable additions to our knowledge of Reptiles, Amphibians, and Fishes. Among Invertebrates, the Crustacea have been especially studied by Jones, Salter, and Woodward. Davidson, Etheridge, Lycett, Morris, Phillips, Wood, and Wright have continued their researches on the Mollusks; Duncan, Nicholson, and others have investigated the extinct corals; and Binney, Carruthers, and Williamson, the Fossil Plants. Numerous other important contributions have been made to the science in Great Britain during the present period.

On the Continent, the advance in Palæontology has, during the last two decades, been equally great. In France, Gervais continued his memoirs on extinct vertebrates nearly to the present date; while Gaudry has published several volumes on the subject that are models for all students of the science. His work on the fossil animals of Greece is a perfect monograph of its kind, and his later publications are all of importance. Lartet's various works are of permanent value, and his application of Palæontology to Archæology brought notable results. The volume of Alphonse Milne-Edwards on fossil Crustacea was a fit supplement to Brongniart and Desmarest's well known work; while his grand memoir on fossil Birds deserves to rank with the classic volumes of Cuvier. Blainville, Duvernoy, Filhol, Hébert, Sauvage and others have also published interesting results on fossil vertebrates.

Van Beneden's researches on the fossil vertebrates of Belgium have produced results of great value. Pictet, Rütimeyer, and Wiedersheim in Switzerland, Bianconi, Cornalia, Costa, Forsyth-Major, and Sismonda in Italy, and Nodot in Spain, have likewise

published important memoirs. The extinct vertebrates have been studied in Germany by Von Meyer, Carus, Fraas, Giebel, Heckel, Haase, Hensel, Kayser, Kner, Ludwig, Peters, Portis, Maack, Salenka, Steindachner, Zittel, and many others; in Holland by Winkler, in Denmark by Reinhardt; and in Russia by Brandt, Eichwald and Kowalewsky.

The fossil invertebrates have been investigated with care by D'Archiac, D'Orbigny, Bayle, Coquand, Cotteau, Deslonchamps, Fromentel, Oustalet, and others in France; Desor, Loriol, Mayer, Ooster, and Roux in Switzerland; Cappellini, Cattulo, Massalongo, Michellotti, Meneghini, Stoppani, and Sismonda in Italy; Barrande, Benecke, Beyrich, Dames, Dorn, Ehlers, Geinitz, Giebel, Gümbel, Feistmantel, Hagen, von Hauer, Hæckel, von Heyden, von Fritsch, Laube, Oppel, Quenstedt, Roemer, Schlüter, Suess, Speyer, and Zittel in Germany, and Angelin, Lindström, Lütkin, and Sars in Sweden. The fossil Plants have been studied in these countries by Massalongo, Saporta, Zigno, Fiedler, Goldenberg, Gehler, Heer, Goeppert, Ludwig, Schimper, Schenk, and many others.

Among the recent researches in Palæontology in other regions may be mentioned those of Blanford, Feistmantel, Lydekker, and Stoliczka, in India; Haast and Hector in New Zealand, and Krefft and McCoy in Australia; all of whom have published valuable results.

Of the progress of palæontology in America, I have thus far said nothing, and I need now say but little, as many of you are doubtless familiar with its main features. During the first and second periods in the history of palæontology, as I have defined them, America, for most excellent reasons, took no part. In the present century, during the third period, appear the names of Bigsby, Green, Morton, Mitchell, Rafinesque, Say, and Troost, all of whom deserve mention. More recently, the researches of Conrad, Dana, Deane, DeKay, Emmons, Gibbes, Hitchcock, Holmes, Lea, McChesney, Owen, Redfield, Rogers, Shumard, Swallow, and many others, have enlarged our knowledge of the fossils of this country.

The contributions of James Hall to the Invertebrate Palæontology of this country form the basis of our present knowledge of the subject. The extensive labors of Meek in the same depart-

ment are likewise entitled to great credit, and will form an important chapter in the history of the science. The memoirs of Billings, Gabb, Scudder, White, and Whitfield are numerous and important; and the publications of Derby, Hartt, Hyatt, James, Miller, Shaler, Rathbun, Rominger, Vogdes, Whiteaves, and Winchell, are also of value. To Dawson, Lesquereux, and Newberry, we mainly owe our present knowledge of the fossil plants of this country.

The foundation of our vertebrate Palæontology was laid by Leidy, whose contributions have enriched nearly every department of the subject. The numerous publications of Cope are well known. Agassiz, Allen, Baird, Dawson, Deane, DeKay, Emmons, Gibbes, Harlan, Hitchcock, Jefferson, Lea, LeConte, Newberry, Redfield, St. John, Warren, Whitney, Worthen, Wyman, and others, have all added to our knowledge of American fossil vertebrates. The chief results in this department of our subject, I have already laid before you on a previous occasion, and hence need not dwell upon them here.

In this rapid sketch of the history of Palæontology, I have thought it best to speak of the earlier periods more in detail, as they are less generally known, and especially as they indicate the growth of the science, and the obstacles it had to surmount. With the present work in palæontology, moreover, you are all more or less familiar, as the results are now part of the current literature. To assign every important discovery to its author, would have led me far beyond my present plan. I have only endeavored to indicate the growth of the science by citing the more prominent works that mark its progress, or illustrate the prevailing opinions and state of knowledge at the time they were written.

In considering what has been accomplished, directly or indirectly, it is well to bear in mind that without palæontology there would have been no science of geology. The latter science originated from the study of fossils, and not the reverse, as generally supposed. Palæontology, therefore, is not a mere branch of geology but the foundation on which that science mainly rests. This fact is a sufficient excuse, if one were wanting, for noting the early opinions in regard to the changes of the earth's surface, as these changes were first studied to explain the position of fossils. The investigation of the latter first led to theories of the earth's for-

mation, and thus to geology. When speculation replaced observation, fossils were discarded, and for a time the mineral characters of strata were thought to be the key to their position and age. For some time after this, geologists, as we have seen, apologized for using fossils to determine formations, but for the last half century their value for this purpose has been fully recognized.

The services which Palæontology has rendered to Botany and Zoology are less easy to estimate, but are very extensive. The classification of these sciences has been rendered much more complete by the intercalation of many intermediate forms. The probable origin of various living species has been indicated by the genealogies suggested by extinct types; while our knowledge of the geographical distribution of animals and plants at the present day has been greatly improved by the facts brought out in regard to the former distribution of life on the globe.

Among the vast number of new species which have been added are the representatives of a number of new orders entirely unknown among living forms. The distribution of these extinct orders, among the different classes, is interesting, as they are mainly confined to the higher groups. Among the fossil Plants, no new orders have yet been found. There are none known among the Protozoa, or the Mollusca. The Radiates have been enriched by the extinct orders of Blastoidea, Cystidea, and Edrioasterida; and the Crustaceans by the Eurypterida and Trilobita. Among the Vertebrates, no extinct order of fossil Fishes has yet been found; but the Amphibians have been enlarged by the important order Labyrinthodonta. The greatest additions have been among the Reptiles, where the majority of the orders are extinct. Here we have at the present date the Ichthyosauria, Sauranodontia, Plesiosauria and Mosasauria, among the marine forms; the Pterosauria, including the Pteranodontia, containing the flying forms; and the Dinosauria, including the Sauropoda—the giants among reptiles; likewise the Dicynodontia, and probably the Theriodontia, among the terrestrial forms. Although but few fossil Birds have been found below the Tertiary, we have already among the Mesozoic forms three new orders: the Saururæ, represented by *Archæopteryx;* the Odontotormæ, with *Ichthyornis* as the type; and the Odontolcæ, based upon *Hesperornis;* all of these orders being included in the sub-class Odontornithes, or toothed birds. Among Mammals, the new groups regarded as orders are the Toxodontia, and the

Dinocerata, among the Ungulates; and the Tillodontia, including strange Eocene Mammals whose exact affinities are yet to be determined.

Among the important results in vertebrate palæontology, are the genealogies, made out with considerable probability, for various existing animals. Many of the larger mammals have been traced back through allied forms in a closely connected series to early Tertiary times. In several cases the series are so complete that there can be little doubt that the line of descent has been established. The Evolution of the horse, for example, is to-day demonstrated by the specimens now known. The demonstration in one case stands for all. The evidence in favor of the genealogy of the horse now rests on the same foundation as the proof that any fossil bone once formed part of the skeleton of a living animal. A special creation of a single bone is as probable as the special creation of a single species. The method of the palæontologist in the investigation of the one, is the method for the other. The only choice lies between *natural derivation* and *supernatural creation*.

For such reasons it is now regarded among the active workers in science as a waste of time to discuss the truth of Evolution. The battle on this point has been fought, and won.

The geographical distribution of animals and plants, as well as their migrations, has received much new light from Palæontology. The fossils found in some natural divisions of the earth are related so closely to the forms now living there, that a genetic connection between them can hardly be doubted. The extinct Marsupials of Australia, and the Edentates of South America, are well known examples. The Pliocene hippopotami of Asia and the South of Europe point directly to migrations from Africa. Other similar examples are numerous. The fossil plants of the Arctic region prove the existence of a climate there far milder than at present, and recent researches at least render more probable the suggestion, made long ago by Buffon, in his "Epochs of Nature," that life began in the polar regions, and by successive migrations from them the continents were peopled.

The great services which Comparative Anatomy rendered to Palæontology at the hands of Cuvier, Agassiz, Owen, and others,

have been amply repaid. The solution of some of the most difficult problems in Anatomy has received scarcely less aid from the extinct forms discovered, than from Embryology; and the two lines of research supplement each other. Our present knowledge of the vertebrate skull, the limb-arches, and the limbs, has been much enlarged by researches in Palæontology. On the other hand, the recent labors of Gegenbaur, Huxley, Parker, Balfour, and Thacher, will make clear many obscure points in ancient Life.

One of the important results of recent palæontological research, is the law of brain-growth, found to exist among extinct mammals, and to some extent in other vertebrates, According to this law, as I have briefly stated it elsewhere: "All Tertiary mammals had small brains. There was, also, a gradual increase in the size of the brain during this period. This increase was confined mainly to the cerebral hemispheres, or higher portions of the brain. In some groups, the convolutions of the brain have gradually become more complicated. In some, the cerebellum and the olfactory lobes have even diminished in size." More recent researches render it probable that the same general law of brain-growth holds good for birds and reptiles from the Mesozoic to the present time. The Cretaceous birds, that have been investigated with reference to this point, had brains only about one-third as large in proportion as those nearest allied among living species. The Dinosaurs from our Western Jurassic follow the same law, and had brain cavities vastly smaller than any existing reptiles. Many other facts point in the same direction, and indicate that the general law will hold good for all extinct vertebrates.

Palæontology has rendered great service to the more recent science of Archæology. At the beginning of the present period, a re-examination of the evidence in regard to the antiquity of the human race was going on, and important results were soon attained. Evidence in favor of the presence of man on the earth at a period far earlier than the accepted chronology of six thousand years would imply, had been gradually accumulating; but had been rejected from time to time by the highest authorities. In 1823, Cuvier, Brongniart, and Buckland, and later, Lyell, refused to admit that human relics, and the bones of extinct animals found with them, were of the same geological age, although experienced geologists, such as Boué and others, had been convinced

by collecting them. Christol, Serres, and Tournal, in France, and Schmerling in Belgium, had found human remains in caves, associated closely with those of various extinct mammals, and other similar facts were on record.

Boucher de Perthes, in 1841, began to collect stone implements in the gravels of the valley of the Somme, and, in 1847, published the first volume of his "*Antiquités Celtiques.*" In this work, he described the specimens he had found, and asserted their great antiquity. The facts as presented, however, were not generally accepted. Twelve years later, Falconer, Evans, and Prestwich examined the same localities with care, became convinced, and the results were published in 1859 and 1860. About the same time Gaudry, Hébert, and Desnoyers, also explored the same valley, and announced that the stone implements there were as ancient as the mammoth and rhinoceros found with them. Explorations in the Swiss lakes and in the Danish shell heaps added new testimony bearing in the same direction. In 1863, appeared Lyell's work on the "Geological Evidences of the Antiquity of Man," in which facts were brought together from various parts of the world, proving beyond question the great age of the human race.

The additional proof since brought to light has been extensive, and is still rapidly increasing. The Quaternary age of man is now generally accepted. Attempts have recently been made to approximate in years the time of man's first appearance on the earth. One high authority has estimated the antiquity of man merely to the last glacial epoch of Europe as 200,000 years; and those best qualified to judge, would, I think, regard this as a fair estimate.

Important evidence has likewise been adduced of man's existence in the Tertiary, both in Europe and America. The evidence to-day is in favor of the presence of man in the Pliocene of this country. The proof offered on this point by Professor J. D. Whitney, in his recent work,[17] is so strong, and his careful, conscientious method of investigation so well known, that his conclusions seem irresistible. Whether the Pliocene strata he has explored so fully on the Pacific coast corresponds strictly with the deposits which bear this name in Europe, may be a question requiring further consideration. At present, the known facts indicate that the American beds containing human remains, and works

[17] Auriferous Gravels of the Sierra Nevada of California. 1879.

of man, are as old as the Pliocene of Europe. The existence of Man in the Tertiary period seems now fairly established.

In looking back over the history of Palæontology, much seems to have been accomplished; and yet the work has but just begun. A small fraction only of the earth's surface has been examined, and two large continents are waiting to be explored. The "imperfection of the geological record," so often cited by friends and foes, still remains, although much improved; but the future is full of promise. In filling out this record, America, I believe, will do her full share, and thus aid in the solution of the great problems now before us.

I have endeavored to define clearly the different periods in the history of Palæontology. If I may venture, in conclusion, to characterize the present period in all departments of science, its main feature would be a *belief in universal laws*. The reign of Law, first recognized in the physical world, has now been extended to Life, as well. In return, Life has given to inanimate nature the key to her profounder mysteries — Evolution, which embraces the universe.

What is to be the main characteristic of the next period? No one now can tell. But if we are permitted to continue in imagination the rapidly converging lines of research pursued to-day, they seem to meet at the point where organic and inorganic nature become one. That this point will yet be reached, I cannot doubt.

REPORT OF COMMITTEE.

SECOND REPORT OF THE COMMITTEE ON AN INTERNATIONAL GEOLOGICAL CONGRESS.

AT a meeting of this Association at Nashville, Tenn., Sept. 3, 1877, your Committee reported that its labors since its organization at Buffalo, New York, August 25, 1876, had resulted in arranging, with the help of the Geological Society of France, for an International Congress of Geologists to be held at Paris in August, 1878. It has now to report, farther, that this Congress, at first announced for the 19th, was finally fixed for the 29th of August, and was duly opened on that day in the palace of the Trocadero, the Minister of Public Instruction presiding for the occasion. Six sittings were held, with Mr. Hébert for president, assisted by many vice-presidents chosen from the various nationalities present;— Mr. Jannetaz being secretary-general, and Messrs. Brocchi, Delaire, Sauvage, and Vélain, secretaries.

The whole number of members enrolled was 328, of which about 250 were in attendance. Of the members of the International Committee were present Messrs. Otto Torell, of Sweden, E. H. von Baumhauer, of Holland, and Messrs. James Hall, J. P. Lesley, and T. Sterry Hunt, of the United States. American geology was farther represented at the Congress by Messrs. George H. Cooke, W. P. Blake, E. D. Cope, and S. C. Chamberlin, with Mr. A. R. C. Selwyn from Canada.

Of other countries, Spain, Portugal, Italy, Switzerland, Belgium, Holland, Denmark, Norway, Sweden, Russia, Austria-Hungary, Roumania and Australia were represented in the Congress, but neither England nor Germany. The papers communicated were forty in number, covering a wide range of subjects, and often giving rise to important discussions. The Acts of this first session of the International Geological Congress are to be published under the direction of the secretaries, the expense thereof being

generously defrayed by the French government. The volume is in press and will soon appear.

A part of the plan suggested by your committee was the organization of an International Geological Exhibition in connection with the Universal Exposition to be held at Paris in 1878, at which were gathered many important geological collections and maps. In furtherance of this plan, the local committee in Paris prepared and published for the use of the Congress, a catalogue of all these, and also of the numerous public and private collections of the kind which were liberally thrown open to the members. The hospitalities extended to the Congress were numerous and highly appreciated, and were terminated by a public dinner at the Hotel Continental. After the adjournment of the Congress, its members were invited to join in the extraordinary session of the Geological Society of France. This included a series of excursions in the vicinity of Paris from the 5th to the 13th of September, in which many of the members took part.

It was decided at the closing sitting in Paris, September 4, that a second session of the International Geological Congress should be held at Bologna in Italy, in 1881, under the honorary presidency of Sella, president of the Accademia dei Lincei of Rome. A local committee of Italian geologists was named, and has since issued a circular, a translation of which is given as an Appendix to this report. The future Congress is declared to be under the high protection of His Majesty King Humbert I, and under the patronage of the city of Bologna, and will be opened September 29, 1881.

The principal subjects proposed for consideration at the coming Congress are comprised under two groups, and for each of these an International Commission was named by the Congress of Paris. The first of these Commissions is to consider the question of Geological Cartography and the adoption of a common system of signs and colors; while to the second Commission is referred the subject of The Unification of Geological Nomenclature. Under this title, as interpreted by the Congress, will be considered all matters relating to geological classification, as well as the value and significance of mineralogical, lithological, and paleontological characters, thus embracing many of the most important problems of geology. In naming these two International Commissions, so far as possible one member was appointed for each country, whose

duty it shall be to organize therein separate local committees for each group, and to make known their constitution to the secretaries of the corresponding Commissions.

For the International Commission on Geological Cartography the American members are Lesley for the United States, and Selwyn for Canada, and for that on Geological Nomenclature James Hall for the United States, and T. Sterry Hunt for Canada. The names of the other members will be given in the Appendix. Your Committee are glad to announce that active preparations are already made in Great Britain and in Germany for the representation of these countries at the Congress of Bologna.

In view of the fact that the work of an International Geological Congress was initiated by this Association, and that it promises to become of permanent and increasing importance, it is believed that it will be for the best interests of geological science that this committee be continued, with power to add to its number; and farther that its scope may with advantage be extended to include the consideration of such questions relating to State or National Geological Surveys as may from time to time arise.

The whole respectfully submitted,

JAMES HALL, *Chairman.*

T. STERRY HUNT, *Secretary.*

The above report having been accepted by the Association, a motion was made and adopted, to the effect that inasmuch as the Committee of this Association, as originally constituted, and as re-organized at Nashville in 1877, had joined to it, with the title of associates, several European representatives of geology, for the purpose of securing international action, and inasmuch as these foreign associates will henceforth be engaged in the local committees for their respective countries, their names be dropped from the present Committee.

At a subsequent meeting of the Committee, held at Saratoga, Sept. 1, 1879, it was decided to add thereto the names of George H. Cooke, James D. Dana, and Clarence King; the other members being James Hall, Wm. B. Rogers, J. W. Dawson, J. S. Newberry, C. H. Hitchcock, R. Pumpelly, J. P. Lesley, and T. Sterry Hunt.

APPENDIX.

Translation of the Circular of the Committee of Organization for 1881.

BOLOGNA, Italy, April 3, 1879.

"The International Geological Congress, which met for the first time in 1878 at Paris, decided in its last sitting that its second assembly should take place in September, 1881, at Bologna in Italy. On the same occasion, the Congress, while conserving to the Paris Bureau its powers until the opening of the session of 1881, named, for the purpose of arranging for this, a committee of organization, composed of Italian geologists, which has fixed its head-quarters in the City of Bologna.

With a view of more certainly arriving at a practical result in the coming session, the Congress of Paris at the same time adopted the following plan.

1. Two International Commissions are named, having for their object the study of the two following questions, which form the basis of the programme.

a. The Unification of Geological Cartography ("Unification des figurés géologiques".)

b. The Unification of Geological Nomenclature.

A third Commission is charged with the study of the rules to be followed in establishing the nomenclature of species in mineralogy and paleontology.

[This last, though appointed to report at Bologna, is a French Commission and not International.—Translator.]

2. These Commissions must send their reports before the end of 1880 to the Committee of Organization, which will cause them to be printed and distributed to the inscribed members, before the opening of the session at Bologna.

A detailed programme indicating the days of sitting, excursions, etc., will be distributed with the reports of the Commissions, or in any case before the opening of the session.

Those who desire to be inscribed as members of the Congress should make application as soon as possible either to the Bureau of the Committee of Organization (65, via Zamboni, Bologna, Italy), to one of the members of the International Commissions, or to one of the [Italian] delegates of the Committee. In making such application, names, titles, and residence should be fully and carefully given.

The subscription for each member is twelve francs, and the treasurer's receipt for this amount entitles the holder to a member's ticket, as well as to the Proceedings and all ordinary publications of the Congress. Tickets will be issued to members at the office of the Congress in Bologna, on and after Sept. 20, 1881."

The above circular is signed by J. Capellini, president of the

duty it shall be to organize therein separate local committees for each group, and to make known their constitution to the secretaries of the corresponding Commissions.

For the International Commission on Geological Cartography the American members are Lesley for the United States, and Selwyn for Canada, and for that on Geological Nomenclature James Hall for the United States, and T. Sterry Hunt for Canada. The names of the other members will be given in the Appendix. Your Committee are glad to announce that active preparations are already made in Great Britain and in Germany for the representation of these countries at the Congress of Bologna.

In view of the fact that the work of an International Geological Congress was initiated by this Association, and that it promises to become of permanent and increasing importance, it is believed that it will be for the best interests of geological science that this committee be continued, with power to add to its number; and farther that its scope may with advantage be extended to include the consideration of such questions relating to State or National Geological Surveys as may from time to time arise.

The whole respectfully submitted,

JAMES HALL, *Chairman.*

T. STERRY HUNT, *Secretary.*

The above report having been accepted by the Association, a motion was made and adopted, to the effect that inasmuch as the Committee of this Association, as originally constituted, and as re-organized at Nashville in 1877, had joined to it, with the title of associates, several European representatives of geology, for the purpose of securing international action, and inasmuch as these foreign associates will henceforth be engaged in the local committees for their respective countries, their names be dropped from the present Committee.

At a subsequent meeting of the Committee, held at Saratoga, Sept. 1, 1879, it was decided to add thereto the names of George H. Cooke, James D. Dana, and Clarence King; the other members being James Hall, Wm. B. Rogers, J. W. Dawson, J. S. Newberry, C. H. Hitchcock, R. Pumpelly, J. P. Lesley, and T. Sterry Hunt.

divisions of their work. They must moreover send their matured conclusions, in the form of reports, to the secretaries of their respective commissions in such time that all the reports of these International Commissions may be in the hands of the president of the Committee of Organization, Prof. Capellini of Bologna, before the end of 1880.

T. S. H.

SECTION A,

MATHEMATICS, PHYSICS AND CHEMISTRY.

ADDRESS

OF

PROFESSOR S. P. LANGLEY,

VICE PRESIDENT, SECTION A.

LADIES AND GENTLEMEN:—

LEAVING to those of wider knowledge the survey of the whole field of scientific labor, it has seemed to me that I could best present to you some account of that branch of it with which I am most familiar, which is that of "Solar Physics."

This study is essentially a modern one. Astronomy, which in the earliest times could only mark the annual path of the sun, or count the stars, with the invention of the telescope still concerned itself more with the motions of the heavenly bodies than with their physical nature. It sought out new methods of precision to fix the places of these stars and to mark out for the navigator the path of the moon on the celestial dial; it united itself intimately with the sister science of mathematics in predicting the places of the heavenly bodies from the law of gravitation, but it was still as a surveyor and marker of boundaries in the field of space that the observer chiefly labored, and we associate the most striking triumphs of the classic astronomy with this work of precision. It is this aspect that appeals even to the imagination, and which is seized as distinctive by the poet of Urania:

> "That little Vernier on whose slender lines
> The midnight taper trembles as it shines,
> A silent index, tracks the planets' march
> In all their wanderings through the ethereal arch,
> Tells through the mist where dazzled Mercury burns,
> And marks the spot where Uranus returns."

These are noble aims, and noble results; but it is curious to see how observers of the last century, who had learned this excellent lesson of precision, had learned no other, and remained indifferent to a great question to which the old methods did not apply. We are called into existence by a great central fire, the sun, by which we continue to exist from one hour to another. What is it? what is this heat which it pours into space, and with whose cessation we shall cease? How long will it continue to feed our lives? A few years ago, with almost the sole exceptions of the Herschels and Pouillet, no one even asked these questions, much less intelligently sought their solution.

It is hard to say to whom the awakening of attention is due; yet if any one were to be named, it should perhaps be the Italian physicist Melloni, "the Newton of heat."

His book, "La Thermochrose," has to me an attraction of its own, for the author, with the ingenuous confidence of his nation, begins, not by describing his thermopile or galvanometer, but by taking the reader into his personal experience, and telling him how even as a child he felt an invincible curiosity about what we have just seen hardly any one else then cared for, and how, rising long before dawn, he loved to seek some quiet spot, to wait there in the silence of the sleeping world the first beams of the sun, and as he felt their warmth and heard the stir of life they awakened round him, how he too was stirred with wonder and interest as to the nature of that mysterious thing, radiant heat, and resolved to give his future to its study. If, to distinguish a cause for wonder and inquiry in what to the common mind has called for neither, be a characteristic of genius, then Melloni must be allowed its possession, and in his but too short years he showed the world how much interest and importance lay in this then neglected study, which so many with clearer knowledge and better methods follow to-day.

Fraunhofer's previous work had prepared the way for the spectroscope, and with the now awakened interest in these questions, its employment by Kirchhoff in 1860 may be said to inaugurate the present study of solar physics, as distinguished from the classic astronomy, which concerned itself with number and measure first, and in a wholly secondary degree with the physical characteristics of the heavenly bodies. This study occupies itself with the former, indeed, but chiefly in aid of other investigations, and

by the study of solar physics then, we mean much more than a telescopic examination of the sun; we mean besides this the analysis of its radiations by the spectroscope, their summation by the photometer and thermopile, the determinations of its heat and the possible effects of changes in it on terrestrial meteorology, and generally the pursuit of all those problems which unite the methods of physics and astronomy.

In 1860 we already knew that the sun was surrounded by an envelope then visible only during total eclipses, and which was surmised to be gaseous; and of the sun itself we knew very little more than that it was a hot globe with spots upon it; for, though Schwabe had observed the periodicity of the spots, and Carrington was already at work, their results were not wholly public, and the facts of the variable velocity of the sun's rotation were rather the surmises of a few than part of the body of acquired knowledge. Since then this branch of astronomy has grown almost to the position of an independent science, and, though it has not yet been distinctly divided into specialties in its turn like its elder sisters, yet we already see a tendency to their formations. Thus, with the study of the motions of the solar surface we associate with the names just mentioned those of Sporer, De la Rue, and Wolf; with eye-studies of the photosphere or solar meteorology, those of Dawes, Secchi, and others; with the telescopic use of the spectroscope those of Huggins, Janssen, Lockyer, Secchi, Young, and Tacchini. The work of mapping the spectrum, begun by Kirchhoff, has been continued by Angstrom, Mascart, and Cornu, while photography, in the hands of Rutherfurd, Janssen, and Draper, has largely superseded telescopic studies of the photosphere, and the list might be enlarged indefinitely. Let us glance at part of the work done by these during the past twenty years, for their labors make the history of our study.

The work of Carrington, completed in 1861, taught us what had before been suspected — both the periodicity of the spots and that this great globe, so far as we can see it, has different periods of rotation, its equatorial zones completing a revolution in less time than its polar ones. We know very little more on this point now, the cause of both phenomena remaining wholly mysterious to-day.

In the next year (1862) an impulse was given to the study of the solar surface by the announcement of a supposed discovery of gigantic individual bodies in it, of from 500 to 1,000 miles in

length, distinct from each other, and existing in countless numbers. This extraordinary statement was not easily disproved, as it is with great difficulty that the real structure is discernible by the best telescopes. Forms, we can scarcely call them "bodies," are undoubtedly there, of a size and in numbers which could only exist on so vast a surface, and which are no doubt the chief immediate cause of the sun's light and heat — but what are their causes in turn, and what is their real nature? The suggestion was made at the time by the then, perhaps, most eminent living astronomer, that they might be, in a sort, living things — *beings*, in fact, whose vital force gave us the solar heat; a suggestion which we may smile at now, but which was received at the time with a kind of awe, as adumbrating some possible truth. Of its author I would speak with all possible respect in citing it, which I do here, as nothing can better indicate the obscurity of our knowledge, even at so recent a period. We may look back on such a possible suggestion and its connection with that "vital force," now itself banished by physiology, as a kind of landmark on the road we have travelled. Our science, young as it is, is old enough to have had its age of fable.

Since that time, in France, in Italy, in England, and here, thousands of telescopic studies have been made with the purpose of defining these forms, and of learning more about the growth of those mysterious objects with which they are associated — the sun's spots, which drew the attention of Fabricius and Galileo, and which still attract our own more than ever to-day, with problems which seem nearly insoluble. Everything we see convinces us that the solar surface in which they are formed is neither a solid nor a liquid, but composed of volumes of whirling vapors; yet through this vapor, which seems to offer no resistance, come eruptions of explosive violence such as one would suppose must arise from the sudden bursting of some rigid shell. The turmoil within the areas of disturbance is so great, the area itself so vast and inclosing such diversities of action, that we are still doubtful how far this action is downward, how far upward.

Under the circumstances, we can hardly say that twenty years of observation in this department have brought us results commensurate with the labor expended, nor have we derived great aid from photography until some recent advances of which I have presently to speak.

A review of our past studies of the corona is a review of the solar eclipses during the past twenty years; for it is a fact, unparalleled in the sciences of obsèrvation, that the opportunities for this knowledge last only minutes, and are separated by intervals of years. Till 1860 it was uncertain whether the protuberances belonged to the sun or moon, but in that year the then newly applied photographic method made it nearly certain that they were parts of the former, and previous surmises that they were extensions of an envelope everywhere surrounding the sun were confirmed. In 1868 some traces of the corona were first photographed. The spectroscope was used upon the prominences, their gaseous nature was proved, and nine of the chromospheric lines were determined; and nearly together Messrs. Janssen and Lockyer made the discovery that these lines could be seen without an eclipse; 1869 brought that eclipse which traversed our own territory, and in this the distinctive coronal line was first observed by Young and by Harkness; while in this, and yet more in the eclipse of 1870 and 1871, we obtained better photographs of the corona, and greatly increased our knowledge of its apparent structure.

It is hardly possible to present even in the briefest way any review here of the separate history of spectroscopic research since 1860, during which time it has been connected with most of the important steps in every field of our study. It has, in the hands of Messrs. Huggins, Zöllner, and Young, made visible to us the forms of the chromosphere, and enabled us to measure the velocity of motions upon the sun otherwise beyond estimate, while at the same time it has given us independent data for the absolute velocity of other suns in space, and for that of the rotation of our own solar photosphere. It has, in the hands of Secchi and others, connected our knowledge of our sun's physical constitution, and perhaps of its past history with that of other suns, and even assumed to give us information whence we might infer something as to their mass, as well as physical constitution, while it has immensely increased the number of lines mapped twenty years since in the spectrum, and modified the ideas we then entertained as to the interpretation of these lines themselves.

The important question of the amount of heat received from the sun has been the subject of almost uninterrupted experiment and study during the period under review, but without essentially altering the data of Herschel and Pouillet which we already pos-

sessed. In this field the French physicists and our countryman, Mr. Ericsson, have been prominent workers, and we have attained results possessing all desirable certitude relatively to our knowledge in other branches.

Investigations on the solar temperature have been carried on by many observers, but with results which are thus far less satisfactory.

I am painfully sensible of the inadequacy of this review of the history of solar physics, but the brief time before me warns me to come from its past to its present. Within the last two years the difficulties I have alluded to, as so great in eye-studies of the solar surface, have been singularly modified by the remarkable advance of solar photography at the hands of M. Janssen. When I recently visited his observatory at Meudon, I found him producing original negatives on a scale of nearly thirty English inches to the solar diameter, and which bear enlargement to nearly ten feet with remarkable precision; and one of these negatives, which presents over a million discrete cloud-forms, can be taken in $\frac{1}{3000}$ of a second. In another branch of photography, that of the reproduction of spectral lines, for which so much is due to Rutherfurd and Draper, I know nothing more surprising than the recent success of Captain Abney (of the Royal Engineers) at South Kensington, who has photographed the red end of the spectrum, and far beyond the red end, to a wave-length of about 12,000 tenth-metres. As this statement may of itself convey no clear idea to some of my audience, let me explain in less technical language that it means we can now photograph objects in absolute darkness — objects which are not luminous — simply by the heat they give out. This is a discovery which obviously lends itself to important practical applications, while it is of further interest as bringing another proof of that identity of heat and light, with radiations differing only in wave-length, long since surmised by physicists, and asserted prominently by Dr. John W. Draper, whose photographs are also the earliest in the path which Captain Abney has carried on by independent methods. Theoretically, there would seem to be no limit to this power of photography so long as objects radiate any heat whatever.

Of recent coronal studies, I have only to speak of the opportunity afforded by the eclipse of last year in our own Western territory. Observed as it was in the pure air of the Rocky Mountains, we found an immense and hitherto almost unsuspected extension of

the corona in the direction of the solar equator, such as to make it increasingly probable that the outer corona and the zodiacal light are different appearances with a common origin. The physical constitution of the inner corona seemed to be modified by the weakness or absence of a former constituent, and perhaps we may say that some additional knowledge was gained as to its telescopic structure and its absolute light, while the polariscopic evidence was contradictory.

In the light of our latest knowledge, what, then, is the corona? We do not know. We have literally had but about twenty minutes in the last twenty years to look at it, and from that brief study it remains every way problematical. The extent of this vast solar appendage is unknown, its constitution is unknown, its function is unknown, and it is still uncertain whether we can devise any means for its study which will free us from this dependence upon momentary glimpses. Our only hope, since the most powerful telescope is useless in our lower atmosphere, seems to be to transport our observatory to some mountain-height, like that of Etna or the elevated table-lands of Colorado. There, even, we can not be sure of seeing it without an eclipse; but there, if anywhere, ingenuity will be hopefully employed in an endeavor to remove the difficulties which bar the way. After spending some weeks this year myself upon Mount Etna, on which the new solar observatory is to be built, I can testify to the excellence of such a station; and yet, when we have sites equally good, I can not but regret that it should be left to others to first enter such a promising field.

Of recent spectro-photographic observation, I may mention the valuable work of M. Cornu, who, working at the other extremity of the spectrum from Captain Abney, has extended it beyond the violet to a wave-length of 2,900, far beyond which the solar spectrum undoubtedly exists, but where M. Cornu finds our own atmosphere to interpose an almost impassable barrier. The solar spectrum, therefore, is now known by photography through three times the extent of the visible portion, and this great gain on our former knowledge may be said to have been completed for us in the past year.

In last November and subsequently, Mr. Lockyer has made the extremely important announcement that, reasoning from analogies furnished by known compounds, he has been able to show that many elements are really compound bodies, which, incompletely

dissociated at the highest temperature we can command, furnish under the form of feeble lines the spectra of their components.

I do not enter here into discussion of points still in debate; but that which has arisen round this and the recent communications of Dr. Henry Draper, at any rate elicits the evidence of the immense labor now requisite in establishing new facts in our science, and the refinement of some of the adverse explanations suggested in controversy shows us to how limited a company of specialists we must look as judges in matters so important.

The instrumental aids of our study have grown in the period under review with the demand for greater accuracy, until the detached prisms of Kirchhoff's apparatus are replaced by trains of automatically adjustable mechanism, giving us in Thollon's recent instrument the equivalent dispersion of thirty prisms of flint, or what has replaced the "gitter" of Fraunhofer, that wonderful product of skill, the Rutherfurd grating, which for a large variety of uses has already supplanted the prism. Observatories especially devoted to solar physics are being established by European governments, as at Potsdam by Prussia, and at Meudon by France. I have already alluded to that on Etna, and I hope it will not be long before we have a distinctly physical observatory within our own territory. There is no step in our power to take which promises so much for immediate advance as the installation of one in a suitably elevated station, for certain investigations can be made *only* under this condition, and no amount of instrumental appliance, patience, or skill, at a lower altitude, supplies their place.

In now reviewing the acquisitions which this twenty years' labor has brought us, we can not but agree that we have achieved a great deal, and yet must admit, with wonder at the field still before us, how little is our progress in comparison with what remains unknown.

We have found out how to detect daily the outbursts from the sun which were before invisible, but we watch these outpourings of enormous forms without yet knowing what drives them forth, without being sure how far our very view is not in part illusion.

We have learned how to study and fix many of the wonderful details of spot-actions without knowing what spots are. We see them presenting themselves in increasing importance through a term of years, and then diminishing, and we attempt to assign a

period to these cycles of growth and decay. This period is often fixed at about eleven years, with a perhaps unjustifiable confidence, for we can not be said to know whether what we have seen in so brief a time is constant or variable, nor whether it be not the mere incident of some greater cycle, whose course began before man was here to see it, and whose term may not be complete till he has gone.

We are possibly now led to ask what our science has taught us on the connection of these remote changes with questions which affect our daily lives, and perhaps to put the utilitarian question, "What is all this worth?"

We find at the present time our study growing into a closer union, not merely with stellar astronomy on the one hand and terrestrial meteorology on the other, but with all the physical sciences, than would once have been supposed possible. Thus, to give a single instance, whatever be the result of the discussions aroused by Mr. Lockyer's statements, it seems likely that we are to look to the analysis of the solar radiations for the most favorable evidence of that resolvability of our so-called elements to simpler forms, which our chemists are now very generally ready to admit as possible.

It is in the solar spectrum that we are now searching for the laws of the molecular groupings which affect the ultimate constitution of matter, and in recent questions as to the real nature of certain terrestrial elements, which our laboratories can not yet deal with, the Mount Sherman observations of Professor Young on the appearance of their analogues in the sun have been accepted by both parties in debates before the Royal Society, as pertinent evidence, the only doubt as to which lies in its interpretation.

Of problems "practical" in the sense that their utility is apparent alike to the learned and the unlearned, there are two at least of the highest importance which now occupy us.

The solar heat, which grows for us the food by which we live, is no doubt in one sense the final cause of every meteorological change, bringing those years of want and years of plenty which are due to local variations of climate, that depend, through a chain of causes very remote and obscure, no doubt, yet finally, upon the sun. We have seen the magnetic needles vibrating all over the globe together at the time of a sudden commotion upon the solar surface; we watch the increase and decrease of auroras, and find we can almost predict their frequency, so apparently united are

they by some mysterious bond with the changes of solar spots; and we look with natural hope for other signs of union which may enable us to anticipate more important effects on our meteorology. Extreme pains have been devoted — in some cases misdevoted — to researches aiming to establish such a connection, by collecting data as to the changes in rainfall, the movements of storms, the prices of grain, and of almost every feature of terrestrial meteorology, in order to see whether these run through periods coincident with those of known changes on the solar surface. It will be admitted by the most utilitarian that the end aimed at is a worthy one, for the practical result of success, such as some believe possible, would be to enable its attainer to predict the price of breadstuffs years in advance, to control the markets of the world; to bestow, if unselfish, an almost priceless knowledge to man, or, if self-seeking, to acquire wealth beyond wish.

I need hardly say that the attempt has thus far been unsuccessful. There is hardly any topic on which there is more popular interest, hardly any on which there is more popular error, than this of the supposed influence of the sun on the weather. By means of the study of what Professor Smythe terms the "rain-band" in the spectrum, we appear to have lately gained increased facility in predicting local weather-changes; but, excepting this comparatively unimportant contribution, studies connected with the sun have as yet done very little for us here, and it seems necessary to say that, as far as prophecy is concerned, none of us are yet prophets, or more able to tell from our knowledge of the sun what the weather will be next week than what the harvest will be next year.

There is another utilitarian aspect of our study about which there is less public interest, but more real promise — I mean that which concerns the direct application of solar heat to arts and manufactures. These are now all using it indirectly — by the water, for instance, which it lifts into the clouds to turn the mills of Lowell or Lawrence, as it flows back to the sea, or by the coal which it stored in former ages to drive our engines to-day. These indirect means use but the feeblest portion of the solar heat, which is in theory capable of furnishing nearly one horse-power for each square yard of the earth's surface under full sunshine.

What we have actually realized in experiments is still considerable.

The visitor to the last Paris Exposition may have seen upon its grounds a machine of strange appearance, in the open air, pointing sunward the axis of an immense reflector, shaped like a truncated cone, which gathered the rays to a linear focus upon the boiler of a working steam-engine, which it drove thus by direct solar heat. Many not dissimilar solar engines have been built in this country and in India, the particular one of which I speak, due to M. Mouchot, having actually realized about one horse-power to ten feet square of surface.

We are startled when we make the computation, to find the immensity of the force thus placed at our disposal, or to see what the utilization of the waste places of the earth would bring us. Upon the limited area of the Adirondack wilderness to the north of us, for instance, the daily wasted sun-power actually realizable, and after every allowance for loss, is many times that of all the estimated steam-power at present in use in the whole world. I am not myself so far utilitarian as to wish to see this use made of our pleasant summer haunts, but there are regions of the earth at present as entirely worthless as that great African desert which it is now proposed to partly reconvert to an inland sea, a sunburned area now apparently hopelessly useless to man, and yet on which an amount of power is every year poured in utter waste which could not be made good by the consumption of all the coal known to underlie the soil of Great Britain.

Such machines as those of M. Mouchot, owing to the expense of construction and attendance, cost more than an engine driven by coal, though the sun supplies its power gratis; but it is simply, it seems to me, a question of time when, with another form which I believe our researches already indicate, such engines may become an economical as well as a mechanical success, and in a larger sense it is still only a question of time when the rapidly consuming coal-beds of Great Britain yield their last, and her manufacturing empire is transferred to countries which have not exhausted their supply. But these will exhaust their own in turn; the stock, though great, is finite and not renewable; and we must look, for the only power we know which can replace coal, to those regions of the earth now desolated by solar heat, and to which future empire may probably tend.

We have considered the past and the present of our study; for its future there remains the solution of all the great problems I have

already alluded to, but these questions are so interlocked that the complete answer to one will probably not be given till we are nearly ready to answer all.

I have spoken of the fallacy of the popular impression of the result of our study as enabling us to predict the weather, or to anticipate the character of coming harvests. Repeating my belief that we as yet know nothing here, or next to nothing, I yet do not mean to disparage the object of such researches, nor even to deny the possibility of their ultimate success. We can look forward, among other fair dreams for our science's future, to a time when it will enable us to predict the years of plenty or play the part of a beneficent Providence, by warning in season against those of famine, which have cost in our time so many million lives in China and in India. These are, I repeat, still dreams only, but we may call them hopes if we will — hopes of which increased knowledge may deprive us, but of which we can not say it may not bring fruition.

There remains among the greatest problems of the future of our science the all-important one to the whole human race of the future constancy of the sun's heat, of which we have, it seems to me, no assurance of the present rate of supply. We have, it is true, every assurance that in the contraction of the solar mass and in the supply of meteoric matter, we have heat to warm the human race for periods almost beyond limit; but we learn also that this heat is tempered to us by a solar envelope, which seems to be, as far as we know, in conditions which do not favor stability. It is constantly being added to by eruptions from within the sun, caused by we know not what, and constantly diminished by some counter-process which we understand as little. When we consider that the thickening of this solar atmosphere would bring back the age of ice, or its thinning carry our polar regions to tropical temperature, and when we remember that rhythmical action, not uniformity, seems to be the law of nature here, we can feel no certainty of the future constancy of the solar heat, nor of our protection against such changes as seem to have befallen other suns in space, and against which we are powerless to guard.

But such considerations of our ignorance and helplessness, while they may prevent us from any undue pride in what our science has already attained, may teach us renewed confidence from the very brevity of our life. These green fields around us were once cov-

ered with glacial ice, and the change has been absolute from that condition to the one of to-day. Yet in the lifetime of any one of the thousands of insect generations which have succeeded each other in these fields, there must have seemed no alteration; and, remembering what instants our own lives are, in a like comparison with the uncounted ages of the sun's history, we may well reckon that our generation shall see no change.

In the little span which is allowed us, however, we will try to learn something more of that source of light, life, and power of which we are materially the creatures; and, if we can leave a knowledge which will not die with ourselves, feel that we have left also the record of a something in us "which owes no homage to the sun."

PAPERS READ.

ON THE OBSERVATIONS OF DOUBLE STARS. By ASAPH HALL, of Washington, D. C.

The existence of errors in the work of an observer which are peculiar to him and to his instrument, and which cannot be eliminated by increasing the number of his observations, is one of the chief difficulties in combining into a final result the labors of many astronomers. These errors being of the nature of constant errors are not recognized by the method of least squares, and it is the existence of such errors that frequently renders illusory our value of the probable error of a result. But it should be remembered that this is not a fault of the method of least squares, in which all errors are considered as purely accidental, and subject only to the laws of chance. We need not therefore be surprised when we see in the determination of a latitude or a longitude an error ten or twenty times as great as the computed probable error, and we should not, as some have done, accuse the method of least squares of giving false results. The unexpected error comes from the constant errors which we had ignored in our previous work, and which are brought to light by the addition of new observations, or by the employment of new methods. In the determination of the orbits of satellites and double stars we labor under the disadvantage that the errors of observation bear a sensible ratio to the values of the quantities measured. This ratio is sometimes so large that these errors may render our result entirely erroneous, and the final result of a long numerical work may become useless. This difficulty is aggravated by the constant errors in the angles of position and the distances measured by different observers, whose observations, especially in the case of double stars, it is necessary to unite into the same calculation.

In order to combine these observations we must know the personal error, or the constant difference, peculiar to each observer.

As soon as micrometrical measurements became accurate, or when Fraunhofer by means of his wonderful skill had supplied astronomers with suitable micrometers, the attention of observers was drawn to this matter, and one of the earliest examples of the comparison of accurate measurements is that between Bessel and the elder Struve. In this work Bessel used the Konigsberg heliometer of six inch aperture, and Struve the filar micrometer of the Dorpat refractor, which has an objective of $9\frac{1}{2}$ inches aperture. A comparison of their measures showed a decided constant difference in the distances, while the angles of position agreed nearly within the limits of their probable errors. The following table shows these differences, arranged according to the distances between the forty-one stars of comparison.

DISTANCE.	STRUVE.—BESSEL.	NO. STARS.
1″.5	—0″.104	5
2 .9	—0 .272	5
4 .1	—0 .200	5
5 .2	—0 .285	5
6 .0	—0 .235	5
8 .1	—0 .235	5
12 .1	—0 .171	5
15 .1	—0 .070	3
26 .5	—0 .093	3

It will be seen that the constant difference in the distances measured by these skilful astronomers is very marked; that this difference reaches a maximum at a distance of about 6″, and that it vanishes at a distance of 26.5″. In the case of two stars at an angular distance of from 3″ to 8″ the constant personal error amounts to from $\frac{1}{10}$ to $\frac{1}{40}$ of the whole distance. Thus in the case of the interesting double star 70 Ophiuchi we might on account of such a difference make an error of $\frac{1}{20}$ in the determination of the semi-major axis of its orbit. The differences given in the preceding table were found from stars that had been observed on several days, and each difference depends on several

stars, so that the accidental errors are nearly eliminated. Bessel and Struve both made investigations to determine their constant personal errors, and each came to the conclusion that his own observations were correct, and that the error must lie in the work of the other.

In contrast with these constant differences it is interesting to examine the probable errors of the observations made by Struve of the brighter double stars, for which of course his measures are more accurate than for the fainter ones. The following table gives the probable errors for the distances and the angles of position, arranged according to the mean distances of the stars. The errors are those of a single distance and a single angle of position.

W. STRUVE'S PROBABLE ERRORS.

MEAN DISTANCE.	PROBABLE ERRORS. DISTANCE.	PROBABLE ERRORS. ANGLE.	NO. STARS.
0″.7	±0″.07	±0″.03	44
1 .5	0 .09	0 .05	111
3 .1	0 .10	0 .06	128
5 .6	0 .12	0 .08	119
9 .8	0 .13	0 .09	51
13 .9	0 .13	0 .10	46
19 .4	0 .14	0 .10	48
28 .2	0 .16	0 .12	48

Bessel's probable errors are nearly the same as Struve's, perhaps a little greater; but it appears from recent investigations that the Königsberg heliometer and Bessel's method of applying it to the measurement of double stars were very nearly free from constant errors. It will be noticed that Struve's determinations of the angle are more accurate than his determinations of the distances. This arises partly from his method of observing, and is not the case generally with observers, many of whom find that for distances greater than 3″ or 4″ their distances are measured with greater accuracy than the angles.

In 1852 Otto Struve began experiments to determine the constant errors of his observations of double stars. He made a very

careful and extensive series of observations of artificial double stars in the years 1853 to 1856, and these observations were repeated in 1866 and in 1876. This is by far the most elaborate investigation of the kind that has ever been made, and the results are interesting. Thus it appears that for stars at an angular distance of 3″ or 4″ the observations of a skilful observer may be in error by as much as five or six degrees in the angle of position: this error depending on the position of the line joining the stars to that of the vertical circle passing through the stars. Another singular result is that all the distances between 2″ and 15″ measured with the filar micrometer by such experienced astronomers as the two Struves, Dembowski and Düner, are too small, the correction reaching a maximum of from 0.2″ to 0.3″ between the distances 5″ and 10″; while on the other hand the distances measured by Bessel within these limits are nearly correct. Struve has tabulated these corrections, and in Vol. IX of the Pulkowa observations, which contains his observations of double stars made from 1839 to 1875, the corrections have been applied both to the angles and the distances. The result, according to theory, should be the true angles and distances of the double stars, or these quantities freed from personal errors. Whatever may be the decision of the question whether corrections deduced in this manner shall be generally introduced into astronomical work, there can be no doubt that Struve has called attention to the essential thing to be done by observers of double stars. This is that they should connect their observations with those of other astronomers by observing at nearly the same time, and repeatedly, and at various hour angles, the same stars; and in this way furnishing the means for computing the systematic corrections of their own observations.

In the winter of 1875-'76 my attention was called to the large constant differences that may exist in the micrometrical measurements of astronomers, a striking example being given in the observations of the satellites of Uranus. I wrote to Struve proposing that he should select a list of double stars which astronomers might observe for the purpose of comparing their observations and deducing their systematic corrections. I learned from him that he and Baron Dembowski were already engaged in such a work, and after adding to the list a few stars the complete list of thirty stars was published by Struve in June 1876. In order that the observations might be made independently, it was understood

that each observer should avoid all knowledge of the results of other astronomers, at least until his own observations were of such a number that the mean result would not be essentially changed by such knowledge. To this rule I have carefully adhered, and at the present time have accumulated very nearly the number of observations intended. Our large refractor at Washington gives us peculiar advantages in the observation of faint objects, and our attention has not been given chiefly to double stars. For this reason I have not made so many observations of the stars selected by Struve as I might otherwise have done; and have assumed that ten observations of each star will give a trustworthy determination of my value of its angle of position and distance. It is my intention to finish my observations on this list during the present year, and as more than three years have passed since the publication of the list no harm can be done, I think, in making known some of the results.

To show the quality of my measurements, I select three of the thirty stars measured. In the following table the first column gives the date of the observation, the second the siderial time, a comparison of which with the right ascension of the star will give the hour angle at which the observation was made; the third and fourth columns give the angle of position and the distance; the fifth the condition of the images on a scale of 5, 1 denoting a very poor, and 5 an excellent condition; the sixth column gives the magnifying power, and the last column the notes on the observations. Following the observations are given the mean results and their probable errors. These observations were all made in the manner that nearly all our micrometrical work has been done, that is with bright wires in a dark field; a method not the most accurate but adapted to the observation of faint objects.

Σ. 2034.

$\alpha = 16^{h}\ 4^{m}.2$: $\delta = +83°\ 59'$: (7.8 and 8) mags.

Date.	*Sid. Time.* h.	*p.*	*s.*	*Image.*	*Power.*
1876.795	20.1	118°.6	1''.25	2.	606.
6.798	19.9	120 .3	1 .30	2.	606.
6.801	19.8	118 .3	1 .34	3.	383.
6.803	19.8	118 .6	1 .13	3.	383.
7.422	15.4	111 .5	1 .28	2.	606.

Date.	*Sid. time.* h.	*p.*	*s.*	*Image.*	*Power.*
7.452	14.4	115 .0	1 .04	3.	606.
7.460	14.4	114 .8	1 .19	2.	383.
7.518	15.2	113 .7	1 .44	2.	383.
7.532	15.4	113 .8	1 .29	2.	383.
8.849	21.6	116 .4	1 .27	3.	383.
8.854	21.7	114 .8	1 .34	2.	383.
8.857	21.8	114 .1	1 .17	3.	383.
8.860	21.1	115 .9	1 .23	3.	383.
9.470	15.0	113 .5	1 .40	3.	606.
9.543	16.6	114 .3	1 .34	2.	606.
9.546	16.5	114 .4	1 .29	3.	606.
9.549	16.6	114. 2	1 .29	3.	606.

Mean Results.

1878.124 $p = 115°.36 \pm 0°.386$

$s = 1''.270 \pm 0''.0160$

Probable error of a single distance $= \pm 0''.066$

" " " " " angle $= \pm 1°.59 = 0''.035$

β Lyrae.

$\alpha = 18^h\ 45^m.5$: $\delta = 33°\ 13'$: (3 and 6.7)

Date.	*Sid. Time.* h.	*p.*	*s.*	*Image.*	*Power.*	
1876.655	18.3	148°.97	45''.87	2.	383.	face north.
6.658	18.2	149 .09	45 .87	2.	383.	" north.
6.661	17.6	149 .29	45 .80	2.	383.	" south.
6.664	18.2	149 .15	45 .75	3.	383.	" south.
6.669	17.9	149 .31	45 .86	3.	606.	" north.
6.675	18.2	149 .16	45 .91	2.	606.	" north.
6.680	18.1	149 .33	45 .80	2.	606.	" south.
6.710	18.2	149 .16	45 .82	2.	606.	" south.
9.543	18.0	149 .10	45 .80	2.	606.	" south.
9.546	18.0	148 .91	45 .83	2.	383.	" east.
9.584	18.6	149 .08	45 .80	2.	606.	" south.
9.587	18.5	149 .12	45 .98	3.	383.	" north.

Mean Results.

1877.636 $p = 149°.139 \pm 0°.0248$

$s = 45''.841 \pm 0''.0120$

Probable error of a single distance $= \pm 0''.0415$
" " " " " angle $= \pm 0°.0859 = 0''.069$

Σ. 2571.

h. m.
$\alpha = 19\ \ 35.3:\ \ \delta = +78°\ 0':$ mags. (7.8 and 8)

Date.	*Sid. Time.* h.	*p.*	*s.*	*Image.*	*Power*
1876.749	19.3	22°.7	11".49	4.	383.
6.760	19.4	21 .7	11 .35	2.	383.
6.781	19.6	21 .9	11 .36	3.	383.
6.784	19.6	21 .8	11 .44	2.	383.
7.460	15.6	21 .0	11 .36	3.	383.
7.518	16.0	20 .9	11 .41	2.	383.
7.532	15.8	20 .9	11 .46	2.	383.
7.534	15.8	20 .7	11 .33	2.	383.

Mean Results.

1877.140 $\quad p = 21°.45 \pm 0.°164$
$\quad s = 11''.400 \pm 0.''0139$

Probable error of a single distance $= \pm 0''.039$
" " " " angle $= \pm 0°.464 = 0.''092$

In the observed angles of position of Σ 2034 and Σ 2571 it will be seen that there appears to be a constant difference in 1876 depending on the hour angle at which the observation was made, but this difference does not reappear in the angles of Σ 2034 observed in 1878. In computing the probable errors I have assumed that all of these differences are accidental and the probable errors of the angles are therefore a little too large. The distances of Σ 2571 are among the most accordant of my measures, while those of Σ 2034 are among the most discordant. For all these stars the observed angle depends on four settings of the position circle, and in the case of β Lyra and Σ 2571 each distance depends on four measurements of the double distance; but the distances of Σ 2034 depend on two measurements of the double distance. β Lyra is one of the bright stars of the list and passing near the zenith of Washington I have been able to vary my position in making the observations. The distance of these stars is nearly equal to the apparent elongation of the outer satellite of Uranus. There appears to be only a slight change in the quantities measured

with the change in the position of the observer, and I have considered these differences also as purely accidental. The star Σ2034 is only six degrees from the North pole and the telescope is therefore always pointed nearly north in observing this star. I have had much trouble in making the observations because the images were frequently confused and indistinct. The condition of things has frequently been as follows: I would be observing stars near the zenith the images being tolerably good; on turning the telescope down toward the north to the star Σ2034 the images at first would be fair, but after a few minutes, and before an observation could be made, the images would become so bad that an observation was impossible, the stars being simply a confused mass of light. This was caused, probably, by the cool north wind blowing against the warm object glass and disturbing its figure. Our large objective is very sensitive to changes of temperature, and will not perform well so long as these changes are rapid. If a large telescope is ever mounted on the lofty plains of the West, which I hope may soon be done, the great daily change of temperature in those regions will be one of the difficulties to be met.

The comparison of the observed values of the same distance and angle of position will furnish the means of reducing the observations of different astronomers to a common standard, and this is all we need. If we could assume that the habits of observers do not change, a single determination of the personal error would be sufficient, but this assumption cannot be made. In order to apply another test to my measures, I have made the following observations: If I select four stars forming a small quadrilateral on the heavens, and observe the six distances which these stars form with each other, and the four angles which the distances contain, if my observations are correct they will satisfy certain geometrical relations. Thus in the case of a quadrilateral the sum of the observed angles ought to equal four right angles. If this condition is satisfied the observed angles are correct, or the errors of the angles compensate each other. Some compensation of this kind would probably take place, but the experiment of subjecting one's observations to a geometrical test is interesting. The four bright stars in the trapezium of Orion furnish a convenient quadrilateral for such a trial, and I have observed the angles and the distances between these stars each on an average fourteen nights; seven nights in 1877 with bright wires in a dark field, and seven

nights in 1878 with dark wires in a bright field. Professor Holden has computed the equations of conditions and adjusted these measures by the method of least squares. The observations were made in the usual manner, each angle of position in 1877 depending on four settings of the position circle, and each distance on two measurements of the double distance; but in 1878, generally each distance depends on four measurements of the double distance. It should be stated also that in 1878 the illumination of the field was quite unsteady. The probable errors of a single observation are as follows:

1877. (bright wires),	Power 383.
for a single distance	$r = \pm$ 0″.060
" " angle	$r = \pm$ 0°.270
" " " at distance 15″.5	$r = \pm$ 0″.073
1878. (dark wires),	Power 383.
for a single distance	$r = \pm$ 0″.050
" " angle	$r = \pm$ 0°.250
" " " at distance 15″.5	$r = \pm$ 0″.068

It appears that in this case the distances and the angles are measured with nearly the same degree of accuracy, and that the difference between the bright and the dark wires is hardly sensible. After the adjustment of the quadrilateral the sum of the angles is in 1877, 360°.02; and in 1878, 359.°62. The values of the probable errors which result from the least square solution are very nearly the same as those above.

These examples are sufficient to show the degree of accuracy attained in measurements with the filar micrometer of the Washington refractor. This is sufficient, I think, to justify our undertaking determinations of stellar parallax.

OBSERVATIONS OF THE TRANSIT OF MERCURY, 1878, MAY 6, INCLUDING A SYSTEMATIC SEARCH FOR A SATELLITE, AND MEASURES OF THE DIAMETER OF THE PLANET. By D. P. TODD, of Washington, D. C.

THE conditions for observing the transit of Mercury at Washington were very favorable. The reduced Washington mean times of observation of the contacts are as follow:—

	d	h	m	s	s	
The first (external) contact,	May 5	22	4	55.4	± 5	weight 2.
The second (internal) contact,		22	7	39.3	± 1	weight 4.
The third (internal) contact,	May 6	5	33	49.7	± 3	weight 3.
The fourth (external) contact,		5	36	44.7	± 4	weight 2.

The weights are assigned according to a scale in which 5 would indicate a perfect observation. A magnifying power of 180 diameters was employed. The observed phases correspond to the diagrams represented at "*External Contact*" and "*Internal Contact*" in figure 2 of Professor NEWCOMB's *Instructions for Observing the Transit of Mercury*, issued by the Naval Observatory.[1] The appearance of these disks at a distance of half a mile had been carefully studied before the transit. It is, therefore, believed that the times above given are those of geometric contact, with as great a degree of accuracy as the assigned weights and probable errors indicate. No hesitation, distortion, nor black drop was observed at any of the contacts.

No light spot was observed on the disk of Mercury—either white or any other color. The disk appeared of a uniform jet blackness throughout. No indication of an atmosphere surrounding the planet was remarked—the limb of the planet was very sharply defined all around.

A systematic search for a possible satellite of Mercury was maintained at suitable intervals during the time of the transit. Moments of favorable definition were chosen for the employment of a magnifying power so high that a satellite having a diameter so large as 40 miles could not have escaped detection. The following table shows the maximum apparent elongation of

[1] See also page 46 of *Reports on Telescopic Observations of the Transit of Mercury, May* 5-6, 1878, forming Appendix II of the *Washington Observations for* 1876.

satellites with various hypothetic periods, assuming ENCKE's mass of Mercury $\frac{1}{4866000}$th that of the sun:—

ASSUMED PERIOD.	MAXIMUM APPARENT ELONGATION AT DISTANCE [9.747]
3.0 hours.	11″
6.0 hours.	17
12.0 hours.	27
1.0 day.	43
2.0 days.	68
3.0 days.	89
30.0 days.	412

As the transit of Mercury was so nearly central, a satellite having a period which it would seem reasonable to assume must have been projected on the disk of the sun. If, however, any such object exists, it would be much more readily detected by the solar light which it must reflect.

The observations were all made with the CLARK equatorial refractor which was used by the Transit-of-Venus party stationed at Campbelltown, Tasmania, in 1874. It has a clear aperture of five inches, and was mounted in the garden of the Naval Observatory, 285 feet east, and 185 feet south of the centre of the smaller dome of the Observatory. The number of the instrument is 860. The full aperture was employed.

The equatorial is furnished with a double-image micrometer, of the AIRY pattern as modified by VALZ. This was employed in a series of measures of diameters of the planet, with a magnifying power of 200. The results of these measures are given in the Table on the following page.

The atmospheric conditions were not favorable for carrying out the original scheme of continuing these measures 90° farther. The unfinished series, however, seems to afford no evidence of ellipticity of the planet. Each result in the column "Apparent

Diameter" is given by the mean of three separate measures of double-diameter of the planet.[2] The value of one rotation of

POSITION ANGLE OF DIAMETER MEASURED.	APPARENT DIAMETER.
357° — 177°	11″.88
357 — 177	11 .80
7 — 187	11 .88
17 — 197	11 .81
27 — 207	11 .80
37 — 217	11 .87
47 — 227	11 .81
57 — 237	11 .86
67 — 247	11 .85
77 — 257	11 .88
87 — 267	11 .80
Mean Diameter,	11 .84

the micrometer-screw was determined by the measurement of a white disk, about two feet in diameter, on a back-ground of jet blackness. The disk was placed at a distance of about 3080 feet.

The distance of Mercury from the earth at the mean epoch of the measures being [9.7465], the mean result, 11″.84, gives

$$6''.604 \pm 0''.004$$

for the diameter of the planet as seen at the distance unity. Assuming a solar parallax of 8″.81, the resulting diameter of Mercury is

4781 kilometers = 2971 miles.

[2] I remark here that the extraordinary agreement of these results is not to be regarded otherwise than merely accidental: an exhibit of all the separate measures of double-diameter indicates discordances which, although they happen to be nearly eliminated in the means by threes, should be regarded as a surer index of the value of the observations.

The following table exhibits the values of this constant resulting from some of the best astronomical determinations, the name of the observer, the sort of instrument used, and the date of the observations: —

DIAMETER OF MERCURY AT DISTANCE 1.	OBSERVER.	INSTRUMENT.	DATE.
6″.6792	BESSEL.	Heliometer.	1832, May 5.
6 .89	MAIN.	Double-Image Micrometer.	1841—1845.
6 .52	BRUHNS.	Wire-Micrometer.	1861, Nov. 11.
6 .606	KAISER.	Double-Image Micrometer.	1865, June—Oct.
6 .229	WOLFF.	Heliometer.	1868, Nov. 4.

A METHOD OF INVESTIGATING THE ERRORS PRODUCED BY IRREGULARITIES IN THE FORM OF THE PIVOTS OF A MERIDIAN INSTRUMENT. By C. A. YOUNG, of Princeton, New Jersey.

VARIOUS methods have been proposed and used for detecting and measuring irregularities in the form of pivots.

The oldest apparatus for the purpose is the contact level of Bessel, arranged in such a manner that the bubble of the level will be disturbed by any irregularities of the pivot surface when the instrument is revolved upon its axis. The level can be made sufficiently delicate to detect any imperfections which would sensibly affect the observations, but unfortunately it does not furnish the data for a direct calculation of the corrections to be applied on account of the errors it detects.

A second method of procedure consists in mounting upon each of the piers a powerful microscope, and observing the movements of a fine dot near the center of the end-face of each pivot. As the instrument is turned in the Ys, the dots ought to describe small circles, and the observed deviations of their actual paths

from these circles will supply data for computing the changes in the direction of the axis, and the corresponding deviations of the line of collimation from the proper plane of rotation. The apparatus, however, is costly, and the observations required are tedious and difficult.

If the instrument has two circles, one near each end of its axis, a set of readings of both circles made for the purpose of determining the errors of graduation will also be available for investigating the figure of the pivots. Few instruments, however, are thus provided.

A still more refined method consists in fitting up the axis of the instrument as a telescope, the axis being made hollow as usual, and furnished with an object glass at one end, and at the other with an eyepiece and micrometer: or it may be fitted up merely as a collimator, with an object glass at one end, and at the other a simple pair of cross wires in its focus. In the first case, we look through the axis at a collimator mounted upon a pier in the prolongation of the axis; in the second, a telescope upon the pier observes the axis itself as a collimator. In either case, the path described by the axis of the instrument during a revolution is immediately deducible from the micrometer observations upon the collimator cross wires.

The only objection to the method—a fatal one, however, in most cases—is that the hole in the pivot is too small to admit of an object glass sufficiently large to give satisfactory definition of the collimator cross. If the length of the axis is three or four feet, the object glass ought not to be less than two inches in diameter, and it had much better be three or four. In very large instruments, like the Meridian Circle at Greenwich, with pivots six inches in diameter, the method answers perfectly.

It has occurred to me that the difficulty might be surmounted in the following manner. Attach firmly to the extremity of the axis of the instrument, a plane mirror three or four inches in diameter, with its plane approximately normal to the axis, and observe it by a telescope, fitted with a so-called collimating eyepiece, and mounted solidly in the prolongation of the axis. Even a small instrument could carry a mirror of this size, and as the object glass of the collimator can be of the same diameter, abundant optical power can be commanded for the measurement of the minute deviations in question. Moreover, *these deviations are*

doubled by the reflection, so that with a given optical and micrometric apparatus the accuracy of the results would be doubled.

Suppose that the instrument has been adjusted for collimation by a pair of opposite collimators in the usual way, and its axis levelled, not by a spirit level, but by a Bohnenberger eye-piece and basin of mercury, using the adjusting screws of the Ys to bring the image of the wires, seen in the mercury, to coincide with the wires themselves. We may now define the "Astronomical axis" of the instrument as a line which is perpendicular to the line of collimation, and horizontal when the telescope is pointed upon either one of its two collimators arbitrarily selected; and this without regard to the figure of the pivots. This astronomical axis, like the optical axis of a crystal, is not merely *one* line of material particles in the instrument, but *any* line which fulfils the conditions—a *direction*, rather than a line; fixed indeed with reference to the line of collimation and the parts of the instrument while rotating upon the Ys, if the instrument is rigid; but not fixed in space during the rotation unless the pivots are perfect in form.

If now the plane of the mirror is perpendicular to this axis, we can readily bring the testing-telescope to coincide with the axis by making the image of the cross hairs, reflected from the mirror, to coincide with the hairs themselves, while the telescope of the instrument is pointed to its collimator. If the mirror is not perpendicular to this axis we must direct the testing-telescope so that the intersection of its wires may lie half-way between the reflected image formed when the instrument is pointed North and that obtained when it is pointed South. The angular distance between the images, in the two positions named, will then be four times the inclination of the mirror, which may be a minute or two of arc without inconvenience and even with advantage, as it is not desirable to have the reflected image too near the intersection of the wires for convenient measurement of the interval. The testing-telescope being thus adjusted, the reflected image should, if the pivots are perfect, describe an exact circle around the intersection of the wires with a radius equal to twice the inclination of the mirror. The deviations of the image from the position it ought to have on the hypothesis of perfect pivots, will be double the angular deviations of the axis, and will determine the aberrations of the line of collimation from a vertical circle passing through the line of the fixed collimators.

If the plane of the mirror's inclination be made coincident with the line of collimation of the telescope, the observations become extremely simple. It is then only necessary to consider the variations in the *distance* of the reflected image from the intersection of the wires; the position angles do not come into the reckoning at all.

It is hardly necessary to add that if the testing-telescope be only approximately adjusted to coincidence with the astronomical axis of the instrument, the observations of the reflected image of its wires will still furnish all the needed data for determining the position and the motions of the axis, with undiminished accuracy, though with slightly increased complication in the calculation.

It would be desirable that the testing-telescope should have, in place of the ordinary eye-piece, a compound microscope, mounted independently of the tube containing the object-glass and reticle. This microscope should be provided with a position micrometer for measuring the distance between the cross wires and their image. With this arrangement there would be no danger of disturbing the direction of the testing-telescope by the manipulation of the micrometer.

The angular value of the micrometer scale could be obtained in various ways—probably most simply as follows. Point the instrument on one of its collimators, and displace it slightly by the screws which adjust it in azimuth. The displacement can be measured directly by its right ascension micrometer, and the displacement of the reflected image in the testing-telescope will be just twice as much.

It might be advisable to substitute for cross hairs in the reticle of the testing-telescope, a thin glass plate carrying a minute black dot, surrounded by one or two concentric circles, to make its identification easy. This could easily be managed by photography.

The mirror must of course be firmly attached to the pivot. In applying the method to a new instrument it would probably be best to make and work it in one piece with the pivot, platinizing or silvering it to give it reflective power. If it were necessary to have a hole through its center for the purpose of illuminating the wires of the instrument, no inconvenience would be involved beyond a slight loss of light in the reflected image.

After reaching Saratoga I learned from our distinguished guest, Professor Struve, that a very similar method has already been

successfully put in practice at Poulkowa by Wagner. He uses a mirror attached to the axis in the same manner, but instead of employing a telescope observing the image of its own reticle, I understand that he uses a microscope viewing the reflected image of a luminous point. His method, therefore, involves the consideration of linear displacements as well as angular, while in the method above proposed we have to do with angular deviations only.

Discovery of the Coincidence of the Bright Lines of the Oxygen Spectrum with Bright Lines in the Solar Spectrum. By Henry Draper, of New York.

The object of this paper is to point out the evidence I have presented to show that Oxygen exists in the Sun, to describe the instrumental appliances employed in the research, and to discuss the objections that have been raised to the conclusions I have reached.

Of course at the beginning of these experiments their outcome could not be foreseen and while the absence of the non-metals in the sun may have seemed to be inexplicable, especially if the Nebular Hypothesis be accepted, yet I did not contemplate any particular endeavor to detect this chemical group. In fact the leading idea at the time of constructing my 28 inch telescope was rather to seek for spectroscopic evidence among the stars and nebulæ of the compound nature of the so-called elements and to determine the true elementary bodies.

The research may properly be said to have commenced about ten years ago. I had at that time already constructed a telescope of 15½ inches aperture which was commenced in 1858 and had taken with it many hundreds of photographs of the Moon. But as the mounting had been contrived for lunar photography and to avoid the Moon's motion in declination, the instrument was not suitable for the especial spectroscopic work contemplated. A reflector of 28 inches aperture was therefore commenced in 1866 and in 1871 it was ready for use. Much time is consumed in con-

structing such an instrument because a variety of difficult problems require to be solved particularly those bearing upon the supporting of the mirror and those connected with keeping a star accurately in one place in the field of the telescope or on the slit of the spectroscope. The great delicacy of adjustment necessary for this latter purpose may be appreciated from the statement that at the focus of this Cassegrain reflector a deviation of one second of arc from the true motion of a star during a photographic exposure of fifty minutes is sufficient to carry the star entirely off the slit of the spectroscope, the slit being sometimes less than $\frac{1}{300}$ of an inch wide. The least magnifying power at the focus is 50 times and hence the errors of going are increased to that extent.

On May 29th, 1872, my first photograph of the spectrum of a star was taken, the spectrum of Vega being photographed by the aid of a quartz prism. During August of that year several spectrum photographs of Vega were made and these showed four strong lines in the ultra-violet region, the least refrangible being near G. On pursuing the subject farther and seeking to ascertain what substance or substances gave rise to these lines, it became obvious that a photographic study of this part of the spectrum for the metals and non-metallic elements was necessary to interpret the results. This, of course, opened out a very large field for experiment which would require many years for its study and hence, as several physicists were engaging in the study of the spectra of the metals I concluded to discontinue the experiments commenced in 1870 on the spectra of the metals and to confine the investigation mainly to the non-metals. The initial step was, however, to obtain a fine photograph of the diffraction spectrum of the Sun so that the wave-lengths of the lines up to O (wave-length 3440 ten-millionths of a millimetre) might be determined with precision.

In the spring of 1873 I published a paper on the diffraction spectrum of the Sun illustrated by a photograph embracing the region from wave-length 4350 near G to 3440 near O, and in the autumn of the same year took photographs of the spectra of several of the non-metals, notably Nitrogen, Carbon and Oxygen. The experiments were interrupted in the spring of 1874 by my going to Washington to superintend the photographic preparations for the United States Observations on the Transit of Venus.

Since that time my experiments have been divided into two parts, an astronomical portion occupying principally the summer

season and a laboratory portion during the rest of the year. The former consisted of photographs and observations on the spectra of the stars, planets and sun; the latter, of photographic work on the spectra of the elements and particularly the non-metals. It was in my city Laboratory that most of the oxygen work has been done and consequently the engine, the Gramme machine, the induction coil and the large spectroscope are generally there.

My first photographs of metallic spectra were taken with such apparatus as happened to be at hand, viz: a couple of Bunsen's batteries, an induction coil giving a spark of one-half inch, and a Hofmann's direct-vision spectroscope. The length of the spectrum from G to H was about half an inch, but, though the dimensions were small, the promise was great. Not long after, on examining a series of photographs of the fluted spectrum of nitrogen taken with more powerful instrumental appliances and with juxtaposed solar spectra, the suspicion that there was a coincidence of some bright bands in the two spectra was suggested. On pursuing the subject with more and more powerful electrical and optical arrangements, the coincidence of bright lines of oxygen with bright lines in the solar spectrum was discovered.

The original apparatus, as has been said above, was on a very small scale, but it was soon replaced by a larger battery, a 2-inch induction coil, and a direct-vision prism of one inch aperture by Browning. The electrical part was made more and more powerful as the research proceeded, the 2-inch induction coil being succeeded by one of six inches, and that in turn by a Ruhmkorff coil capable of giving a spark of seventeen inches. The battery was eventually superseded by a Gramme dynamo-electric machine which can produce a current powerful enough to give, between carbon points, a light equal to 500 standard candles. When this machine is properly applied to the 17-inch induction coil, it will readily give 1,000 10-inch sparks per minute. These, being condensed by fourteen Leyden jars, communicate an intense incandescence to air, and light enough is produced to permit of the use of a narrow slit, and of a collimator and telescope of long focus.

Since 1877, when the first publication of the discovery of oxygen in the Sun was made, still further improvements, especially in the optical parts, have been completed, so that I am now enabled to photograph the oxygen spectrum with four times the dispersion then employed. For the sake of clearness, it is best to give a

brief description: 1st, of the electrical part; and 2nd, of the optical part.

The electrical part consists of the Gramme machine and its driving engine, the induction coil, the Leyden jars, and the terminal or spark compressor. An advantage the Gramme has over a battery is in the uniformity of the current it gives when an uniform rate of rotation of its bobbin is kept up. Of course this implies the use of a prime mover that is well regulated. The petroleum engine of one and a half horse-power I have employed is convenient and safe and does this duty well. As to the Gramme itself, it is only needful to call attention to a modification of the interior connections. In one form the bobbin of wire which revolves between the magnets is double, so that the current produced may be divided into two. Under ordinary circumstances, where the machine is used to produce light, both sides of the bobbin send their currents through the electro-magnets. But if the whole current be sent through a quick-working break circuit into an induction coil, the electro-magnets do not become sufficiently magnetised to produce any appreciable effect. It is expedient, therefore, to arrange the connections so that one-half of the bobbin gives a continuous current through the electro-magnets and keeps up the intensity of the magnetic field, and then the current from the other half of the bobbin may be used for exterior work, whether continuous or interrupted.

At first a Foucault mercurial interruptor was arranged to make and break the current passing into the primary circuit of the induction coil; but during the past year, by carrying the rate of rotation of the Gramme up to 1,000 per minute, the strength of the current has been so much increased that the mercury was driven violently out of the cup, and hence it was essential to arrange a mechanical break in which solid metal alone was used. This has been accomplished by fastening on the axis of the Gramme bobbin a wheel with an interrupted rim, which serves the purpose well.

As to the induction coil, it is only needful to say that it gives a good thick spark, which is limited to twelve inches to avoid the risk of injuring the insulation. The Leyden jars are fourteen in number, having altogether seven square feet of coating on each surface.

The arrangement of the terminals from the Leyden jars to get the steadiest and brightest effect has offered great difficulties.

The condensed spark taken in the open air or in a gas under atmospheric pressure pursues, if unconfined, a zigzag course, and this is apt to produce a widening of the lines in the photographed spectrum. But, after many experiments, it turned out that the spark might be compressed between two plates of thick glass, or, better yet, between two plates of soapstone. If the interval between the plates was directed toward the slit of the spectroscope the lateral flickering of the spark was prevented, and yet at the same time the spark was freely exposed to the slit without the intervention of glass or any substance on which the volatilized metal from the terminals could deposit. Very early in this research it had become apparent that Plücker's tubes could not be employed with electrical currents of more than a certain intensity, partly on account of the deposit that took place in the capillary portion, and partly because the terminals became so hot as to melt and crack the glass. Moreover, it was desirable to use one terminal of iron, so as to be sure that the spectrum of the gas was correctly adjusted to the solar spectrum, and this is impracticable with Plücker's tubes. An additional advantage arises from the soapstone plates, viz: the temperature of the small volume of air between the terminals is materially increased, and increased brightness results. I have tried the effect of warming the air by passing it through a coil of brass tube maintained at a bright red heat, but this does not seem to make any perceptible difference when the terminals are enclosed in the spark compressor.

The optical part of my apparatus has undergone many modifications. At first a Hofmann direct-vision prism was combined with a lens of six inches focus; this was soon after replaced by a Browning direct-vision prism and a lens of eighteen inches focus, the latter being arranged for conjugate foci, so that it was virtually as if collimating and observing lenses of thirty-six inches focus were employed. The final system, perfected this winter, consists of a collimator of two inches aperture and twenty-six inches focus, succeeded by two bisulphide of carbon prisms of two inches aperture and an observing or photographing lens of six feet six inches focal length. These prisms belong to Mr. Rutherfurd and are the same he made for producing his celebrated solar prismatic spectrum. This gives a dispersion of about eight inches between G and H and enables me to get original negatives on a scale about half the size of Angström's charts in the Spectre

FIG. 1.

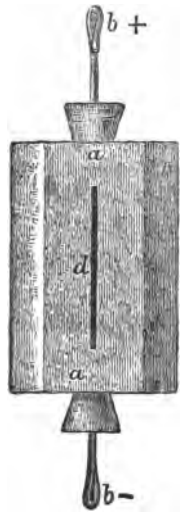
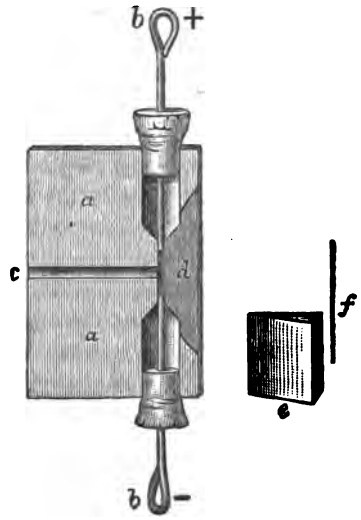


FIG. 2.



SPARK COMPRESSOR. — 1, front view; 2, section in plane of narrow opening; *aa*, soapstone; *bb*, terminals; *c*, aperture for introducing gases; *d*, narrow opening to spark; *e*, right-angled prism; *f*, slit of spectroscope.

FIG. 3.

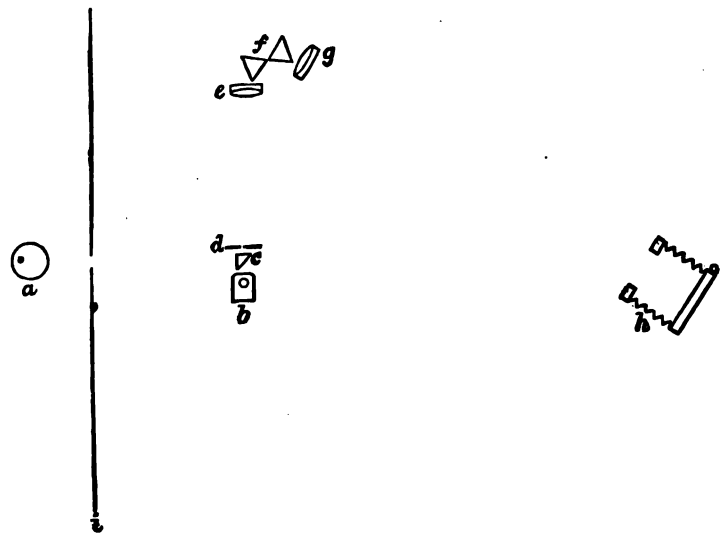


DIAGRAM OF PHOTOGRAPHIC SPECTROSCOPE. — *a*, heliostat mirror; *b*, spark compressor; *c*, right-angled prism; *d*, slit; *e*, collimator; *f*, two bisulphide prisms; *g*, photographic objective; *h*, camera; *i*, window shutter.

Normal du Soleil. When it is remembered that the light produced by the electric current in the spark compressor is scarcely equal to one standard candle, it will be realized that this great dispersion nearly attains the limit of present possibility. By comparison I have found, when the electric arc from this Gramme volatilizes iron, the light is sixty times stronger than the most vivid incandescence of air that I have produced.

The slit of the spectroscope is about one inch long, and opposite the lower half is placed a right-angled prism which serves to bring in a beam of sunlight from a heliostat. We thus have the solar spectrum and the air spectrum upon the plate at the same time, so that the two spectra on the negative are, strictly speaking, simultaneously produced. Moreover, by the aid of a magnifier we can ascertain, just previous to an exposure, whether the adjustments are in the best order. It is not commonly known that, to obtain the last degree of exactness in coincidence between a solar and an air spectrum, many precautions are necessary, and that is the reason it is desirable to have iron vapor present at one of the poles so as to determine the reliability of the coincidence by comparing iron in the spark spectrum with iron in the Sun.

Having thus alluded to some of the principal peculiarities of the apparatus constructed for this research, it is proper in the next place to point out the nature of the evidence afforded by the photographs of the presence of oxygen in the Sun. The first photographs were on so small a scale that they did not even give rise to a suspicion of this fact, and it was not until 1876 that I felt sufficiently sure to make any publication. At this time the original negatives were about two inches long from G to H, and they bore an enlargement of three or four times quite well. The Albertype printed in 1877 in Nature, the Comptes Rendus, and the American Journal of Science, was produced from such an enlargement. Since that time, in order to meet the criticism that perhaps the dispersion was not sufficient to disclose the lack of coincidence if such existed, I have increased the dispersion four times and am thus enabled to make enlarged photographs on a scale about twice the size of Angström's chart. Enlargements of the juxtaposed spectra of air and Sun on this scale are now presented for inspection.

Of course an enlargement never does justice to the original from which it was produced, and, in order to study the matter faithfully,

the negative must be examined carefully with a magnifier. Beside this, owing partly to the fact that the solar spectrum has suffered from absorptive influences, both in the Earth's atmosphere and in the solar atmosphere, the conditions under which the oxygen spectrum is seen when compared with the spark spectrum are modified. In fact, a critical study of the two spectra demands that each line of oxygen should be separately photographed with the corresponding region of the Sun's spectrum, so as to reproduce as nearly as possible the same conditions for each. As an instance of the modifications which may be caused by the solar atmosphere, the superposition of absorption lines on the bright lines of oxygen may be mentioned. If, as seems to be the case, the stratum giving the oxygen spectrum in the Sun lies deeper than the reversing layer in which iron exists, I see no reason why an iron absorption line, for instance, may not fall upon an oxygen bright band. In support of this supposition that oxygen is photospheric, it may be stated that, though I have examined the chromosphere on many occasions, I have not as yet seen the bright oxygen lines project beyond the apparent limb of the Sun as observed in the spectroscope, although several of the chromosphere lines catalogued by Young were readily visible. On consulting with Professor Young, he expressed the opinion that the oxygen groups near G did not appear as bright lines in the chromosphere, even under the exceptionally favorable circumstances he enjoyed at Sherman. For the purpose of continuing the study of this point, and also of examining small areas on the Sun, faculæ, spots, etc., Alvan Clark & Sons are constructing a special spectroscope for me which can give the dispersion of twenty heavy flint prisms and can bear high magnifying power.

If it be conceded that there are bright lines in the spectrum of the solar disk, which seems to be the opinion of several physicists, and especially Lockyer, Cornu and Hennessy, the question of their origin naturally attracts attention. It seems that there is great probability, from general chemical reasons, that a number of the non-metals exist in the Sun. The obvious continuation of this research is in that direction. But the subject is surrounded by exceedingly great obstacles, arising principally from the difficulty of matching the conditions as to temperature, pressure, etc., found in the Sun. Any one who has studied nitrogen, sulphur, or carbon, and has observed the manner in which the spectrum

changes by variations of heat and pressure, will realize that it is well-nigh impossible to hit upon the exact conditions under which such bodies exist at the level of the photosphere. The fact that oxygen, within a certain range of variation, suffers less change than others of the non-metals has been the secret of its detection in the Sun. It appears to have a greater stability of constitution, though Schuster has shown that its spectrum may be made to vary. I have already begun an extended series of experiments on the non-metals; but the results exhibit such confusion that their bearing cannot at present be distinctly seen. In the case of nitrogen the broad bands between G and H exhibit, under the most intense incandescence, a tendency to condense into narrow bands or lines, and indeed there are some sharp lines of nitrogen in the photographs now presented.

It does not follow, therefore, that the bright bands of oxygen are necessarily the brightest parts of the solar spectrum. Other substances may produce lines or bands of greater brilliancy.

There is also another cause for the difference of appearance in a bright-line spectrum produced in a laboratory and bright lines in the Sun. While the edges of a band in the spark spectrum may be nebulous or shaded off, the corresponding band in the solar spectrum may have its edges sharpened by the action of adjacent dark lines due to one or another of the metallic substances in the Sun.

On the whole, it does not seem improper for me to take the ground that, having shown by photographs that the bright lines of the oxygen spark spectrum all fall opposite bright portions of the solar spectrum, I have established the probability of the existence of oxygen in the Sun. Causes that can modify in some measure the character of the bright bands of the solar spectrum obviously exist in the Sun, and these, it may be inferred, exert influence enough to account for such minor differences as may be detected.

In closing, it may be well to give some idea of the amount of labor and time this research has already consumed, and this cannot be better done than by a statement of the production of electrical action that has been necessary. Each photograph demands an exposure of 15 minutes, and, with preparation and development at least half an hour is needed. The making of a photograph, exclusive of intermediate trials, requires,therefore, about 30,000 10-inch sparks, that is 30,000 revolutions of the bobbin of the

Gramme machine. In the last three years the Gramme has made 20 millions of revolutions. The petroleum engine only consumes a couple of drops of oil at each stroke, and yet it has used up about 150 gallons. Each drop of oil produces two or three 10-inch sparks. It must also be borne in mind that comparison spectra can only be made when the Sun is shining, and clouds therefore are a fertile source of loss of time.

APPENDIX.

[On account of the absence of Professor Draper, the President of the Association, Professor Barker, read Professor Draper's paper and also extracts from the Astronomical Register of the discussion which took place at the Royal Astronomical Society last June. As this is the expression of the best English authorities upon the conclusions reached in the memoir, he thought it would be a matter of general interest to members of the Association.]

"After the reading of the paper, Dr. Draper showed some exquisitely sharp negatives of the solar and oxygen spectra, which he had obtained, and handed round some paper enlargements, some two feet long, for inspection by the meeting.

"Mr. Ranyard: After the reception that has been given to Dr. Draper, I do not think I need say anything about the importance of the research he has undertaken. When a couple of years ago he sent over copies from his former photographs on a much smaller scale, I then ventured to say that I thought the probability of the proposition which he laid down was very great indeed, amounting to some thousands to one, and I should like now to point out how enormously the probability has been increased by these more recent experiments. If Dr. Draper has increased his dispersion four times he has not merely increased the probability of his case four times, but he has increased the value of every coincidence he shows four times. On looking at the original photographs (which show the coincidences more sharply than the paper prints) I counted eighteen oxygen lines, and, therefore, the increase of probabilty on the present occasion, as compared with the former occasion, is as four to the power of eighteen to one, a very enormous number. There are two or three ways of looking at the probability of the proposition which Dr. Draper has laid down, that the bright lines of oxygen coincide with the bright lines in the solar spectrum. In the first place, there is the chance that the centre of no single line of oxygen should fall opposite to a dark line or space in the solar spectrum. If a line were thrown at random beside the solar spectrum the chance that it should fall opposite to a bright part of the solar spectrum would be as the total breadth of the bright part of the solar spectrum to the total breadth of the dark part of the solar spectrum. Let us suppose that the breadth occupied by dark

lines in the solar spectrum is equal to the breadth occupied by bright lines (probably as seen with high dispersion this is well within the truth) then the chance of any oxygen line falling opposite to a bright line or interspace in the solar spectrum would be one-half, and if the eighteen lines of oxygen had been thrown down at random beside the solar spectrum, the chance that the centre of all the lines should fall opposite to bright spaces would be one divided by two to the power of eighteen. In addition to this we must take into account the chances of the centres of the bright lines appearing to coincide with the centres of the bright interspaces where they do coincide, for in some instances the interspaces are double the breadth of the corresponding oxygen line, the oxygen line being on one side and coinciding with one edge of the interspace; but this is accounted for by the fact that there are probably other bright lines in the solar spectrum besides oxygen lines, and two such bright lines happen, in some instances to fall together. Then, also, it must be remembered that the light of the bright lines of the solar spectrum has suffered absorption in the solar atmosphere, and in the earth's atmosphere, so that they may be modified by the superposition of absorption lines. The observations of the bright lines seen at the limb of the Sun renders it probable that the layer of the solar atmosphere, which gives rise to the dark lines, lies above the layer from which we receive the light of the bright oxygen spectrum, for no bright oxygen lines are seen in the chromosphere. So that it is possible to conceive that the oxygen lines of the solar spectrum may be modified as we observe them by the superposition of dark lines, and this appears in one or two instances to have been the case; but the character of the bright interspaces is very little changed. If, after examining the photographs, anybody has still any doubts as to the case made out by Dr. Draper, I think that he will feel obliged to them if they will state their objections, and give him an opportunity of discussing them.

"Mr. Christie: I do not feel exactly competent to enter on this question very deeply, but Dr. Draper has very kindly given me an opportunity of examining his very beautiful photographs, and I cannot help expressing my great admiration at the splendid results he has achieved. He has obtained photographs of the spectrum of oxygen which, as far as my rather limited acquaintance with the subject goes, are far superior to anything else of the kind; but that is quite another question from proving the existence of oxygen in the Sun. I am afraid that is a very difficult question he has undertaken. If he could prove it, I think these photographs would go a very long way. I do not see myself, that there is, as he has expressed it, very much more to be done in the matter. But I am sorry to say it seems to open up to me rather a hopeless prospect, because we are brought face to face with a great difficulty. Dr. Draper was very kind in explaining to me his views, and he did not at all shirk the difficulties of the case. I hope I may be justified in alluding to them, simply for the sake of getting at the truth. According to Dr. Draper's supposition, the solar spectrum is made up of a continuous spectrum with dark absorption

lines, and also bright lines superposed upon it. Now, the ordinary spectrum, which up to the present time we have supposed that we had to deal with, was a continuous spectrum with dark lines, but when you superpose on this bright lines, so faint that you cannot distinguish their brightness from the general background of the spectrum, it is evident that the problem becomes more complicated. I do not want to express any opinion one way or the other. I am in the position of a sceptic; it may be an unfortunate position, but I think it is truly a scientific position. Now, taking the position of a sceptic, one has to examine these photographs and look to whether Dr. Draper has shown the coincidences as Mr. Ranyard asserts; if not, his probabilities fall to the ground. In more than one instance I find an oxygen line opposite a broader bright space in the solar spectrum, which appears of identically the same brightness in its whole breadth. If the broader space consists of two or more bright lines, as has been suggested, we have two difficulties to contend with; in the first place we have to show that there are other substances which would give lines corresponding to the unoccupied breadth of the interspace, and in the second place we have the fact that these lines are undistinguishable in brightness from the oxygen lines. Again, each of the oxygen lines is fuzzy at the edges, and as there is nothing analagous in the solar spectrum, we have to suppose that the fuzzy edges are cut off by adjacent dark lines. Now, if we are to make use of probabilities, I would ask what is the probability of a pair of dark lines falling in every case exactly at the edges of an oxygen line? We must also take into account the fact that former physicists have failed to identify any of the bright lines of oxygen with dark lines in the solar spectrum, and therefore we start with the fact that none of the oxygen lines can fall opposite to dark lines.

"Mr. Proctor said: There are one or two points I should like to mention. I do not think that Mr. Christie has sufficiently taken into account the importance of the fact that all the oxygen lines fall entirely opposite to bright interspaces in the solar spectrum, and that none of them even partially overlap dark lines. With regard to the general character of the solar spectrum, I would like to ask those who have more especially studied the subject, whether it does not seem probable from antecedent considerations that the solar spectrum should be purely gaseous in its character, that is to say, that there should be bright and dark lines, but no continuous background of spectrum. Perhaps some of you have considered the bearing of Mr. Croll's researches on this matter. He considers that the earth affords evidence that the solar system has been in existence for more than 20,000,000 of years, whereas, if the Sun has been giving out energy as at present for 20,000,000 years, we know that it cannot have derived it from shrinking from even an infinite volume to a globe as large as the photosphere. I am not inclined to agree with him in his explanation that the solar energy may in part have been derived from the impact of stars, but rather think that it points to the fact that the real mass of the Sun lies very much within the photosphere, and that if there is any solid

or liquid nucleus, it is only at a depth of many thousands of miles below the photosphere. If that is the case, I would ask whether it is antecedently probable that there should be any continuous background in the solar spectrum. If the photosphere is purely gaseous, we should only have bright bands interfered with and modified by absorption lines.

"Dr. Gladstone: I have listened with the greatest attention to Dr. Draper. When the photographs first came over I was not convinced, but certainly he has produced results, which, as Mr. Ranyard has shown, have largely increased the evidence of their being real coincidences between the oxygen lines and bright spaces in the solar spectrum. There seems to be still a great question as to whether the solar spectrum is made up only of bright and dark lines, or whether there is a background of continuous spectrum. I am not disposed to give up the idea that we have a continuous spectrum underlying these dark lines, but think that it is certain that we have also bright lines mixed with the dark. We know that when we look at the edge of the Sun there are bright lines corresponding to hydrogen, and some other elements to be seen, but there are no oxygen lines. Now, I would suggest that this shows that the oxygen never rises to the level of the chromosphere, so as to be seen at the limb of the Sun, and probably that is just the reason why we see its lines as bright lines and not as dark lines, for it never gets up to a level where it is sufficiently cool to form dark lines. We can easily understand that, with so much iron and magnesium vapor, all the oxygen as it rushes upward to the higher levels may enter into combination and fall in a rain of oxides.

"Dr. Huggins said that he had examined Dr. Draper's photographs, and was overwhelmed with a sense of the large amount of conscientious labor and care which he had evidently bestowed upon the investigation. Dr. Draper had made out a *primâ facie* case, which entitled him to demand a careful examination of the evidence he had brought forward; but for his own part he should like to suspend his judgment until he had had an opportunity to reëxamine that part of the spectrum. He preferred to wait for a little light, a little sunlight, on the subject, but he wished now to state how thoroughly impressed he was with the cautious and careful experimental arrangements which Dr. Draper had adopted.

"Capt. Noble: It seems to me, looking at the photographs impartially, that if we are to deny the evidence supplied by some of the coincidences, and notably by this group of four lines, and accept Mr. Christie's dicta, we literally should have no tangible evidence as to the existence of any element in the Sun at all.

"Mr. Ranyard: I should like to refer to one or two objections raised by Mr. Christie. I understood him to urge as an objection that there are a great many bright spaces which have not been matched with the bright lines of non-metallic elements. But I would remind him that there are also many dark lines which have not been matched with the lines of known elements. Perhaps they will never be matched, for the conditions in the Sun may not correspond to the conditions obtainable in our laboratories. With regard to the bright lines falling opposite interspaces

which are broader than the bright lines of oxygen, the probability is as Mr. Christie states, very great against there being two adjacent bright lines of exactly equal brightness, but it must be remembered that we are not examining the bright lines themselves, but only photographs of the lines, and that the bright parts of these photographs are what would be called by photographers over-exposed, and, consequently, the gradations of brightness are very much obliterated. Again, I understood Mr. Christie to say that if, instead of matching oxygen lines with interspaces, you began the other way, you ought to find the brightest lines of the spectrum matching the oxygen lines, but this involves the assumption that oxygen gives brighter lines than any other element in the Sun. But I would ask what reason we have for assuming that oxygen gives brighter lines than any other element? With regard to the probability of there being a continuous background of brightness in the solar spectrum, it should be remembered that there are theoretical considerations which render it probable that there is always a continuous background more or less faint between the bright lines in the spectrum of a gas — when the pressure is considerable the brightness of the continuous part of the spectrum is conspicuous; but theoretically there will always be a continuous spectrum corresponding to the short interval of time after the impact of molecules during which the jar of the collision lasts. In the free path between the impacts they give out the characteristic wave lengths, but however rare the gas I suppose there will always be some continuous spectrum corresponding to the impacts, and with the spectra of a great many gaseous elements superposed the continuous spectrum may be conspicuous. We need not, therefore, assume if we should find evidence of such a continuous spectrum that there is any solid or liquid matter in the photosphere; and if it should turn out that there are no oxygen lines above the photosphere, it will not, I think, follow that there is no oxygen there, for there seems to be evidence that the spectrum of some of the elements changes materially at different altitudes, for example, the 1474 line is the brightest of the lines in the corona, but it is a very faint line at the level of the reversing layer, and D_3 is a very bright line in the lower chromosphere, but there is no dark line corresponding to it.

"Mr. Christie: I should not have risen except that reference had been made to my remarks. I do not know that I should say very much, but I think I may remark with reference to this question of coincidence, that everything turns upon the exactness of the coincidence, and whether these are actually coincidences or not. I am not quite prepared to admit that these coincidences are perfect; in fact, I should say there are even coincidences of dark lines with some of the oxygen lines. I admit that it is a matter of judgment, and I should be sorry to say positively that there are such coincidences with dark lines. But there is considerable uncertainty in the matter. As Dr. Draper has explained there is a great difficulty in establishing coincidences, and you have to adjust your apparatus until you match coincidences by the known lines of iron. It seems some of these do not coincide exactly with the dark lines in the sun. I

only alluded to that as being one of the difficulties we have to contend with. With regard to Mr. Ranyard's remarks as to the eye perceiving differences of brightness which the photographs do not show, I would merely wish to ask whether he has examined with his eye different parts of the spectrum, for there is a certain part in the neighborhood of the G lines which I have examined and find the photograph gives exactly the same appearance as is seen with the eye, i. e., the whole space is of equal intensity. I do not think there is much difference between the photograph and the spectrum as seen with the eye. The only object of my remarks was to clear the ground and to point out what it is we are assuming when we predicate the existence of oxygen as giving bright lines in the sun. I do not dispute it, but only point out the difficulties we must face in order that they may be fairly met.

"Mr. J. Rand Capron: There is one question I should like to ask Dr. Draper, and that is, whether he had tried any experiments with the tube spectrum of oxygen?

"Dr. Draper: A great many.

"Mr. J. Rand Capron: The spark taken in air would probably hardly agree with the spectrum of oxygen near the sun's body. I have had occasion to photograph simultaneously the tube spectrum of hydrogen and the air spark spectrum at ordinary pressures. The tube spectrum of hydrogen showed four hydrogen lines perfect throughout, but only one of these lines was represented in the spectrum of air at ordinary pressure, so that it is possible certain oxygen lines present in the sun may be absent in the spark spectrum.

"Dr. Draper: I have taken the oxygen spectrum under a great many different circumstances. I began with tubes containing oxygen and compounds of oxygen, but the difficulty is that you are limited to rather small dispersion, because you cannot get brightness enough for a larger apparatus. Then the difficulty of having iron terminals so as to show a good coincidence is a serious one. So when I made the spark-compressor I arranged a contrivance at the back which would enable me to let in oxygen and the other gases between the terminals, and after various experiments with oxygen I find that it seems to suffer less change with altered conditions than a great many of the other elements I have experimented on. I have clearly shown that the bright lines coincide with bright spaces in the solar spectrum. The minor differences may be fairly attributed to such changes of condition as Mr. Rand Capron has referred to. With regard to Dr. Gladstone's remark, which was that probably we should not find in the chromosphere the lines of the oxygen spectrum; that is precisely what I hope will be the case, although I am going to look as hard as I can for them. I should like to see them if they are there, but I shall be better satisfied if they are not.

"A cordial vote of thanks was then passed to Dr. Draper."

[The photographs of the oxygen spectrum with juxtaposed solar spectrum, were also presented to the French Academy of Sciences in Paris, at the meeting of June 23, 1879, by M. A. Cornu. M. Faye made the

following remarks, which Professor Barker translated from the Comptes Rendus.]

"I cannot refrain from adding some words to the brilliant communication that the Academy has just heard. Everything leads us to believe that the constitution of the photosphere and its marvellous alimentation, are due to alternate phenomena of chemical combination and dissociation operating at divers temperatures in the mass of the Sun under the influence of ascending and descending vertical movements. Such at least is the idea I have arrived at, by the study of spots, of the problem which I think I have presented in all its fulness. Naturally, the richness in oxygen of the compounds which constitute the earth's crust, though the proportion diminishes little by little as we descend, ought to cause us to believe that this same element should play an analogous part in the Sun; but it is a remarkable thing that up to the present, spectrum analysis has not given any trace of it. On the other hand, it showed that round that star there was a vast atmosphere of hydrogen almost pure and very much rarefied, of which certain portions, frequently drawn downward by mechanical action of solar whirlwinds, gave origin, in ascending again, to the phenomena of the protuberances.

Mr. H. Draper has, however, succeeded in discovering the oxygen, not in the chromosphere, but in the photosphere, where it discloses itself by bright lines. It is obvious that if this gas is dissociated at a depth, it is immediately taken up by multiple combinations in the region and at the temperature of the brilliant surface. I see in these facts the hope of a confirmation and above all of an extension of the views I have put forth on the constitution of the Sun; but whatever may be the fate that the progress of spectrum analysis reserves to them, I express here my admiration for the discovery of Mr. Draper, and I hope that his results, so well confirmed by the photographic proofs that our learned member M. Cornu has shown to the Academy, will not delay in being universally accepted by competent judges."

On the Color Correction of Achromatic Telescopes. By Wm. Harkness, of Washington, D. C.

Although much has been written on the theory of the achromatic telescope, I am not aware that any attempt has hitherto been made to treat the color correction rigorously as a function of the wave length of the light, and, on that account much obscurity, and some positive error, has crept into the text books on the subject.

The theory given in the following pages is based upon fundamental equations which neglect the thickness of the lenses, as has always been done heretofore, and which suffice to give the refractive indexes to scarcely more than four places of decimals. All the subsequent operations upon these equations are rigorously accurate; and it would have been useless to attempt greater precision in the refractive indexes, while the thickness of the lenses is neglected. As achromatic telescopic objectives are usually composed of two lenses, rarely of three, and hardly ever of a greater number, it has been thought sufficient to write the equations in the form applicable to triple objectives, but no difficulty will be experienced in extending them to a greater number of lenses, when necessary.

Our fundamental equations are

$$\frac{1}{f} = (\mu - 1) \left\{ \frac{1}{r} + \frac{1}{\rho} \right\} \tag{1}$$

$$\mu = a + b\gamma^2 + c\gamma^4 \tag{2}$$

in which

$f =$ the principal focal distance of any lens.

$\mu =$ the refractive index of the lens.

$r =$ the radius of curvature of the first surface of the lens.

$\rho =$ the radius of curvature of the second surface of the lens.

$\lambda =$ the wave length of the light.

$\gamma = 1 \div \lambda$.

$a, b, c =$ certain coefficients, determined from not less than three properly situated values of μ.

Equation (2) is Cauchy's dispersion formula. Now put

$$\frac{1}{r} + \frac{1}{\rho} = \mathrm{A} \tag{3}$$

and suppose a series of lenses, such that

$$\frac{1}{f_1} = (\mu_1 - 1)\,\mathrm{A}_1;\ \frac{1}{f_2} = (\mu_2 - 1)\,\mathrm{A}_2;\ \frac{1}{f_3} = (\mu_3 - 1)\,\mathrm{A}_3 \tag{4}$$

These lenses being very thin, let them be placed in contact with each other; and let the equivalent focal distance of the whole combination be f. Then, by a well known optical theorem,

$$\frac{1}{f} = (\mu_1 - 1)\,\mathrm{A}_1 + (\mu_2 - 1)\,\mathrm{A}_2 + (\mu_3 - 1)\,\mathrm{A}_3 \tag{5}$$

Substituting the values of μ_1, μ_2, μ_3, from equation (2), putting

$$\left.\begin{aligned} C &= A_1(a_1-1)+A_2(a_2-1)+A_3(a_3-1) \\ D &= A_1b_1+A_2b_2+A_3b_3 \\ E &= A_1c_1+A_2c_2+A_3c_3 \end{aligned}\right\} \quad (6)$$

and arranging the terms according to the powers of γ, we have

$$f=\frac{1}{C+D\gamma^2+E\gamma^4} \quad (7)$$

This equation expresses the relation between the focal distance of the combination and the wave length of the light. It shows that when white light enters an objective there will generally be an infinite number of foci, situated one behind the other, and all contained between the two values of f which correspond to the limiting values of γ. For our purpose, however, it will be more convenient to consider f as the ordinate, and γ as the abscissa, of a curve which we will designate as the focal curve. To investigate its properties, we differentiate with respect to f and γ, and obtain

$$\frac{df}{d\gamma}=-2\gamma f^2(D+2E\gamma^2) \quad (8)$$

Putting the left hand member of this expression equal to zero, we find

$$\gamma^2=-\frac{D}{2E} \quad (9)$$

Differentiating (8) a second time

$$\frac{d^2f}{d\gamma^2}=2f^3\gamma^2(2D+4E\gamma^2)^2-f^2(2D+12E\gamma^2) \quad (10)$$

Substituting the value of γ^2 from (9), this becomes

$$\frac{d^2f}{d\gamma^2}=4Df^2 \quad (11)$$

which shows that, so long as D remains positive, the curve is convex toward the objective, and the value of γ given by equation (9) corresponds to the minimum focal distance.

An achromatic objective, or more accurately and with greater generality, a corrected objective, is one in which all rays of the kind for which the correction is made are brought to as nearly as possible the same focus. For example: if an objective is corrected for visual purposes, then the rays which produce the greatest effect upon the human eye must all be brought as nearly as

University of MICHIGAN

possible to the same focus; or, if the objective is corrected for photographic purposes, then the rays which act most energetically upon silver bromo-iodide must all be brought as nearly as possible to the same focus. This condition will evidently be fulfilled when the rays in question have the minimum focal distance; or in other words, when they satisfy equation (9). Thus it appears that this equation determines the correction of the objective, and for that reason it will be called the achromatic equation, and the particular value of γ which satisfies it will be designated as γ_0.

To find the relative values of A_1, A_2, A_3, in a corrected objective, we substitute in (9) the values of D and E from (6). The resulting expression for the middle lens is

$$-A_2 = \frac{A_1(b_1+2c_1\gamma_0^2)+A_3(b_3+2c_3\gamma_0^2)}{(b_2+2c_2\gamma_0^2)} \tag{12}$$

which shows that one of the lenses must be of the opposite kind from the other two,—that is, two may be convex, and one concave; or *vice versa*.

To find the equivalent focal distance of the whole combination for the ray λ_0, (9) gives

$$D = -2E\gamma_0^2 \tag{13}$$

Substituting this in (7)

$$f_0 = \frac{1}{C-E\gamma_0^4} \tag{14}$$

Replacing C and E by their values from (6)

$$f_0 = \frac{1}{A_1(a_1-c_1\gamma_0^4-1)+A_2(a_2-c_2\gamma_0^4-1)+A_3(a_3-c_3\gamma_0^4-1)} \tag{15}$$

Substituting the value of A_2 from (12), and putting

$$\left.\begin{aligned} n &= \tfrac{A_3}{A_1} \\ L &= (a_1-1)(b_2+2c_2\gamma_0^2)-(a_2-1)(b_1+2c_1\gamma_0^2)+\gamma_0^4(b_1c_2-b_2c_1) \\ M &= (a_3-1)(b_2+2c_2\gamma_0^2)-(a_2-1)(b_3+2c_3\gamma_0^2)+\gamma_0^4(b_3c_2-b_2c_3) \end{aligned}\right\} \tag{16}$$

we obtain finally

$$f_0 = \frac{b_2+2c_2\gamma_0^2}{A_1(L+nM)} \tag{17}$$

The ordinate of the focal curve for the ray λ_1, is the difference between the focal lengths of the objective for the rays λ_0 and λ_1. To find it we have

$$\frac{1}{f_0}-\frac{1}{f_1}=(C+D\gamma_0^2+E\gamma_0^4)-(C+D\gamma_1^2+E\gamma_1^4)=D(\gamma_0^2-\gamma_1^2)+E(\gamma_0^4-\gamma_1^4) \tag{18}$$

But $$\frac{1}{f_0}-\frac{1}{f_1}=\frac{f_1-f_0}{f_0 f_1} \qquad (19)$$

and putting $f_1-f_0=\Delta f_1$, this becomes

$$\Delta f_1=f_0 f_1\left\{\frac{1}{f_0}-\frac{1}{f_1}\right\} \qquad (20)$$

Substituting for the quantity within the brackets its value from (18); and replacing D and E by their equivalents from (6)

$$\Delta f_1=f_0 f_1\{(A_1b_1+A_2b_2+A_3b_3)(\gamma_0^2-\gamma_1^2)+(A_1c_1+A_2c_2+A_3c_3)(\gamma_0^4-\gamma_1^4)\} \qquad (21)$$

Substituting the values of A_2 and $A_3 \div A_1$ from (12) and (16), and putting

$$N=b_1c_2-b_2c_1$$
$$P=b_2c_3-b_3c_2 \qquad (22)$$

we obtain the important expression

$$\Delta f_1=A_1 f_0 f_1(\gamma_0^2-\gamma_1^2)^2\frac{N+nP}{b_2+2c_2\gamma_0^2} \qquad (23)$$

If a star is viewed through a carefully focused achromatic telescope, and if the surface in the focus of the eye-piece is designated as the focal plane: then, of the infinite number of images which equation (7) shows will be formed, some will be situated before, and some behind the focal plane, but only one will coincide exactly with it. The cones of rays which form the images situated before and behind the focal plane will necessarily have a sensible diameter at their intersection with that plane, and their combined effect will be to produce a fringe of colored light around the image of the star, as seen through the eye-piece. This fringe is the secondary spectrum, and its magnitude, for light of any given wave length, will evidently depend upon the value of Δf_1. Hence, to destroy the secondary spectrum, Δf_1 must be made equal to zero. Equation (23) shows that this will be the case for a triple objective when

$$N+nP=0 \qquad (24)$$

or for a double objective when

$$N=0 \qquad (25)$$

As yet no materials have been discovered whose physical properties are such as to satisfy these conditions. We therefore proceed to investigate what form an objective constructed of any

given materials must have in order to render the secondary spectrum a minimum.

Substituting in (23) the value of A_1 from (17), we find

$$\Delta f_1 = f_1 (\gamma_0^2 - \gamma_1^2)^2 \frac{(N+nP)}{(L+nM)} \tag{26}$$

In the right hand member of this equation, n is the only quantity which depends upon the form of the objective. Considering it as variable, and differentiating, we obtain

$$\frac{d(\Delta f_1)}{dn} = f_1 (\gamma_0^2 - \gamma_1^2)^2 \frac{PL-MN}{(L+nM)^2} \tag{27}$$

To make Δf_1 a minimum, such a value must be attributed to n as will reduce the right hand member of (27) to zero. This condition gives at once, $n = \infty$; which will be the case when r and ρ are both infinite ; as is evident from equations (16) and (3). The objective is then reduced to two lenses, and a piece of very thin plano-parallel glass. As the latter cannot appreciably affect the color correction, it may be dismissed from further consideration ; and thus it appears that from any three pieces of glass suitable for making an objective, but not fulfilling the conditions necessary for the complete destruction of the secondary spectrum, it will always be possible to select two pieces from which a double objective can be made that will be superior to any triple objective made from all three of the pieces.

The focal curve being tangent to the focal plane at the point corresponding to the wave length λ_0 ; if we assume the spherical aberration to be perfectly corrected for light of all degrees of refrangibility, then the image of a star formed upon the focal plane by light of wave length λ_0 will be a point, and the linear semi-diameter of the image of the same star formed by light of wave length λ_1 will be the semi-diameter of the cone of rays of that wave length at the point where it cuts the focal plane. Therefore we have

$$f_1 : a :: \Delta f_1 : s_0'' \tag{28}$$

in which a is the semi-aperture of the objective, and s_0'' is the required semi-diameter of the cone of rays of wave length λ_1. Combining (28) with (26), we find

$$s_0'' = a (\gamma_0^2 - \gamma_1^2)^2 \frac{N+nP}{L+nM} \tag{29}$$

This is the expression for a triple objective. In the case of a double one, n becomes zero, and (29) reduces to

$$s_0^{ii} = a\,(\gamma_0^2 - \gamma_1^2)^2 \frac{N}{L} \tag{30}$$

which shows that in a double objective properly corrected for any given purpose, the linear semi-diameter of the secondary spectrum is absolutely independent, both of the focal length of the combination, and of the curves of its lenses; and depends solely upon the aperture of the combination, and the physical properties of the materials composing it.

If a telescope armed with an achromatic eye-piece is carefully focused upon a star, and then the image of the star is viewed through a prism held before the eye-piece; it will be seen that the eye does not adjust the focal plane tangent to the focal curve, but places it somewhat further from the objective, in such wise that the plane cuts the curve in two points, which we will designate as γ_m and γ_n. For these points we must have

$$\frac{1}{C + D\gamma_m^2 + E\gamma_m^4} = \frac{1}{C + D\gamma_n^2 + E\gamma_n^4} \tag{31}$$

which gives

$$-\frac{D}{E} = \gamma_m^2 + \gamma_n^2. \tag{32}$$

But by (9) we have

$$\gamma_0^2 = -\frac{D}{2E} \tag{33}$$

Combining this with (32), we find

$$\gamma_0^2 = \tfrac{1}{2}(\gamma_m^2 + \gamma_n^2) \tag{34}$$

which gives the relation between γ_0 and any pair of points at which the focal plane may cut the focal curve.

We have next to consider how the value of γ_m can be found; and for that purpose a method partly arithmetical, and partly graphical, seems most convenient. The data required are, the values of Δf for a number of different values of γ, and the relative intensity of the light at each of these values of γ. The values of Δf must be computed by means of equation (26); and the relative intensity of the light may either be determined experimentally, or taken from published tables. For visual intensity, the table given by Fraunhofer may be employed; and for photographic intensity, the curves published by Captain Abney contain all that is required.

For the sake of definiteness, let us suppose that the value of γ_m is to be determined for an objective corrected for visual purposes. We begin by laying down an axis of abscissas, and graduating it into a scale of wave lengths. Here, however, it must be observed that the brightness of any part of a spectrum depends not only upon the inherent brightness of the light at that point, but also upon the degree of dispersion employed. As Fraunhofer's determinations of the relative brightness of different parts of the spectrum were made with a flint glass prism having a refractive index of 1·63 for the ray D; and as such an instrument produces much greater dispersion at the violet end of the spectrum than at the red end; it follows that our scale of wave lengths must be, not a scale of equal parts, but such a scale as existed in the spectrum employed by Fraunhofer. The wave length of the brightest ray is approximately 5688, and through that point in the scale, and at right angles to the axis of abscissas, the axis of ordinates must be drawn. Then, from the computed values of Δf, a sufficient number of points must be laid down to determine the focal curve, and that curve must be drawn. At the points whose wave lengths correspond to the principal Fraunhofer lines, lines must be drawn through the focal curve, parallel to the axis of ordinates; the length of each line being proportional to the relative brightness of the spectrum at the point where it is situated, and the center of each line coinciding accurately with the focal curve. Through the extremities of these lines a closed curve must be drawn. The figure thus obtained will be termed the illumination diagram, because it exhibits the amount and distribution of the light at the focus of the objective. The eye will necessarily place the focal plane in the position where this light will produce the greatest effect upon the retina; which is equivalent to saying that the focal plane must pass through the center of gravity of the diagram. Hence, to find the position of the focal plane, we have only to cut out the diagram (which should be drawn upon rather stiff paper), and balance it upon a knife edge held parallel to the axis of abscissas. The reciprocals of the wave lengths of the points of intersection of the knife edge with the focal curve will then be the values of γ_m and γ_n.

The method just explained may be employed to determine the difference between the positions of the principal focus of the same telescope when used for different purposes. For example, if it

were required to find the interval between the visual and photographic foci of a telescope, two illumination diagrams would be drawn — one for the visual, and the other for the photographic rays — and the difference between the positions of the focal plane in the two diagrams would be the required difference of foci.

As the magnitude of the secondary spectrum of a star is measured by the semi-diameter (at the point where it intersects the focal plane) of the cone of rays having the maximum focal distance; it follows that in an objective corrected for visual purposes, the secondary spectrum is diminished by the fact that the eye places the focal plane somewhat further from the objective than the apex of the focal curve. To find the amount of this diminution, we remark that for light of wave lengths corresponding to the points where the focal plane cuts the focal curve, the semi-diameter of the cone of rays is zero; while for light of any other wave length, the semi-diameter of the cone of rays, at the point where it intersects the focal plane, is proportional to the distance between that plane and the point of the focal curve corresponding to the wave length of the light. Hence, the effect of moving the focal plane into a position further from the objective than the apex of the focal curve, will be to diminish s_0^{ii} by a constant which is numerically equal to the value of s_0^{ii} for light whose wave length is that of the point at which the focal plane intersects the focal curve. Modifying equation (30) in accordance with these principles, it becomes

$$s_m^{ii} = a \left\{ (\gamma_0^2 - \gamma_1^2)^2 - (\gamma_0^2 - \gamma_m^2)^2 \right\} \frac{N}{L} \qquad (35)$$

in which γ_m is the reciprocal of the wave length corresponding to either of the two points in which the focal plane cuts the focal curve; and s_m^{ii} is the semi-diameter, at the point where it cuts the focal plane, of the cone of rays whose wave length is λ_1.

The exact nature of the color correction of a telescope can be determined by placing the focal plane in a number of different positions, and observing the corresponding values of γ_m and γ_n. These values being substituted in equation (34), several independent values of γ_0 can be deduced, the mean of which will probably be very near the truth.

The conclusions reached in the preceding pages may be summed up as follows:

1st. From any three pieces of glass suitable for making a cor-

rected objective, but not fulfilling the conditions necessary for the complete destruction of the secondary spectrum, it will always be possible to select two pieces from which a double objective can be made that will be superior to any triple objective made from all three of the pieces.

2d. The color correction of an objective is completely defined by stating the wave length of the light for which it gives the minimum focal distance.

3d. An objective is properly corrected for any given purpose when its minimum focal distance corresponds to rays of the wave length which is most efficient for that purpose. For example, in an objective corrected for visual purposes the rays which seem brightest to the human eye should have the minimum focal distance; while in an objective intended for photographic purposes the rays which act most intensely upon silver bromo-iodide should have the minimum focal distance.

4th. In double achromatic objectives the secondary spectrum (or in other words, the diameter, at its intersection with the focal plane, of the cone of rays having the maximum focal distance), is absolutely independent both of the focal length of the combination, and of the curves of its lenses; and depends solely upon the special color correction adopted, the aperture of the combination, and the physical properties of the materials composing it.

5th. When the focal curve of an objective is known; and the relative intensity, for the purpose for which the objective is corrected, of light of every wave length is also known; then the exact position which the focal plane should occupy can readily be calculated.

6th. It may be remarked incidentally that in an objective corrected for photographic purposes, the interval between the maximum and minimum focal distances is less than in one corrected for visual purposes. Hence, a photographic objective has less secondary spectrum, and is better adapted to spectroscopic work, than a visual objective.

These conclusions are strictly correct for a system of infinitely thin lenses in contact, refracting light according to the law involved in equation (2); but for a different law of dispersion, or if the thicknesses and distances apart of the lenses are considered, they may require modification.

Modern Star Places, with Suggestions relative to Future Co-operation among Meridian Observers. By Lewis Boss, of Albany, N. Y.

At the present time there are about forty observatories engaged in the determination of star places by means of meridian instruments. In each of at least a majority of these institutions, this work is an important, if not the most important feature of the total astronomical activity. In most of the National observatories more than one-half of a large working force is so engaged. Any suggestions, therefore, which point to a better division of labor, to the remedy of defects, or to improved methods of observation are of great importance.

A few years ago while I was employed in a research to ascertain the declinations of the principal fixed stars, from published material, with the greatest possible precision, it became necessary for me to consult more or less critically, all the important observatory publications relating to the declinations of stars. One who has pursued such a course of study cannot fail to be struck with the vast accumulation of material in this department of Astronomy, and must admire the skill with which much of it has been produced and collected for the use of the investigator. It would be both presumptuous and unjust to make general complaint against the character of these efforts, or to expect the product to be entirely free from criticism. It is only when erroneous methods are persisted in, after experience has shown the remedy, and when the following of bad methods is both numerous and respectable, that general criticism on the methods and results of past researches becomes proper as well as useful.

I shall, therefore, proceed to show what appear to me the most evident and important faults in the general administrative features of meridian work past and present, and to call attention, briefly, to the general plan of work which is now sanctioned by most eminent observers. I shall confine myself to the consideration of these general features, because it is on these that the question, how to get the most accurate results for the greatest number of objects, principally depends.

The general discussions which arise from a knowledge of star places and their variations require the number of places considered to be very great; and it is only when some distinguishing

feature is specifically attached to a given star, that it becomes an object of particular interest. Stars which are used for reference, or which are remarkable on account of parallax or proper motion belong to the class of special stars; all others belong to a class in which, for theoretical uses, the position of any one star is as important as any other of the same magnitude. The fact that a given star of the latter class has been well observed in the past is the best excuse for letting it alone in the present. The neglect of this excuse is the most common, but by no means the most important fault of modern meridian work. The fault has not been so glaringly evident in the choice of observing lists, as in the accumulation of observations on individual stars. Suppose, that at a given observatory, three thousand observations are to be devoted to miscellaneous stars; it is obviously better that one thousand stars should each be determined three times, than that three stars should each be determined one thousand times. The requirements of the case are such that it is undoubtedly better to have three observations each of one thousand stars brighter than the seventh magnitude, than to have ten observations each of three hundred stars. Yet if one attempts to determine, from published material, the places of such fifth and sixth magnitude stars as are without great individual interest, he will be struck with the very uneven distribution of the data at hand for determination. He will also find that when one of these stars has been at all observed with certain instruments, the number of observations is as likely to be greater than ten as less. Happily, there is now very little need for exhortation in this respect. There is now a tendency among meridian observers to equalize and lessen the number of observations upon individual stars, and particularly to search out and observe stars whose positions for the present epoch are less accurately known than others of the same magnitude and degree of interest. Of the first tendency, the great zone work of the *Astronomische Gesellschaft* is a conspicuous example. Among others, Professor T. H. Safford has done excellent service in arranging his recent catalogue[1] so as to indicate what is needed in the way of observation for a broad belt of stars, extending from $+20°$ to $+70°$ of declination, and by recommending to the attention of astronomers, just the stars upon which they can do most effective service.

[1] Mean Declination of 2018 Stars, Washington, 1879.

The second and most important criticism, which applies in very many instances to modern meridian work, relates to the general plan of operations, and springs from the impossibility of making absolute determinations of star places which shall not be liable to large systematic corrections. In the present stage of investigation, however, it is of less consequence that a catalogue of star positions shall be free from large systematic errors than that the correction itself shall not be subject to sudden and anomalous changes in value with progressive changes in its argument; always provided that adequate means of comparison with known systems of star places are presented, either in the catalogue itself or in the circumstances of observation upon which the positions are based. Now increased accuracy and fulness of knowledge of star positions may be promoted in two ways: *first*, by ascertaining as nearly as possible absolute positions,—measuring the co-ordinates of each star as if that were the only one in the heavens: *secondly*, by measuring the relative positions of stars in the same neighborhood, relying upon researches of the first class to give the absolute co-ordinates of one or more stars in that region, by means of which knowledge the whole group becomes determined. In a general sense, these operations may be illustrated by the methods of geodetic triangulation, where the determination of primary points constitutes an operation entirely distinct from that which is directly concerned with details. If secondary and tertiary work faithfully correlates the geography of areas surrounding one or more such points, absolute reference to equator and first meridian can be made always more and more precise by repetition of the primary triangulation. Thus, a thousand points may be made to depend upon two or three principal ones, and simply by improvement in accuracy of the positions of these two or three fundamental points, each individual of the thousand is correspondingly benefited. If we admit that the determination of an absolute position is relatively far more difficult than the interpolation of a differential position among others already known, the obvious economy of such an arrangement does not require comment. That this truth has been ignored in conspicuous instances by modern observers, I can only attribute to the force of tradition.

It is true, that at the beginning of the present era of exact observation, and while instruments and skill in using them were constantly improving, each practical astronomer who wished to

determine star places with precision was compelled to make his observations fundamental. Having no data of superior authority as to the places of the principal stars and the elements of refraction, whatever his purpose he must first determine these. Thus we have the celebrated catalogues of Bradley, Piazzi, Groombridge, Bessel, Struve, Angelander and others previous to 1840. But with these fundamental catalogues once in existence, regard for economy would seem to have dictated either one of two distinct courses,—a strictly fundamental determination of star places, with thoroughly independent investigations of instrumental corrections, and the elements of atmospheric refraction; or, differential observation based upon a catalogue of known star positions, compiled from the best existing fundamental catalogues. I know of but three instances of strictly absolute determinations of declination made within the last forty years. I refer to the two Poulkowa series (1845—1865) made with the Ertel vertical circle, and the series made at Leiden ten years ago. These determinations undoubtedly present by far the most valuable material for the discussion of absolute declinations which has appeared during the time mentioned. By contrast, all other efforts, during the same period which profess the same purpose, judged by the degree of success they have attained in securing absolute results, seem at least wasteful of labor. The trouble is that these latter efforts contemplate *both* the objects which we have indicated. Failure in securing good absolute results would be matter of less regret, if the mixture of methods did not operate prejudicially to the attainment of good secondary work.

With Right Ascensions the case is somewhat different, and we have consequently less trouble with that co-ordinate.

Among the disadvantages arising from the mixture of methods, to which allusion has been made may be reckoned:—

First, loss of precision in the determination of relative positions;

Second, less certainty in the amount of systematic correction required;

Third, and most serious of all, comparative loss in the amount of material which can be produced with a given expenditure of labor.

The first point may be practically illustrated with lessons drawn from experience. On page 160, Appendix H, Report of the

United States Northern Boundary Commission, will be found a "table of weights," by means of which the relative precision, in the differential sense, of various declination systems, can be judged. They are derived from a careful discussion founded on comparisons of individual systems with the Normal System of the work cited. Weight one there corresponds to a probable error of $\pm$".30. Commencing with 1845, and considering first those declinations in the production of which mixed methods were followed, we find that the following authorities do not reach weight one in any case: Radcliffe, 1845; Armagh, 1840; Madras, 1850; Santiago, 1851 and 1855; Radcliffe, 1858; Edinburgh Annual Results; Melbourne, 1862. Of the same class of catalogues the following reach weight one at approximately the number of observations set opposite to each.

Observatory.	*Mean Date.*	*No. Obs.*	*Observatory.*	*Mean Date.*	*No. Obs.*
Greenwich	1845	7	Cape G. H.	1858	6
Washington	1847	10	Washington	1864	10
Cambridge	1848	5	Greenwich	1864	3
Greenwich	1851	9	Melbourne	1868	5
Paris	1853	6	Washington	1868	10
Washington	1856	20	Radcliffe	1868	150(?)
Cambridge	1856	5	Greenwich	1870	6
Greenwich	1857	3	Washington	1872	10

The numbers for Washington and Cambridge catalogues can only be estimated because the actual number depends upon the distribution of observations in separate years, and may in selected cases be larger or smaller than the numbers given. Taking now the catalogues during the same period, which are founded on standard catalogues by the method of interpolation or differential observation, we have as numbers of observation necessary to produce weight one: —

Observatory.	*Mean Date.*	*No. Obs.*	*Observatory.*	*Mean Date.*	*No. Obs.*
Paris	1856	4	Brussels	1865	3
Brussels	1856	53	Bonn	1866	8
Paris	1862	2	Leipzig	1867	8
Brussels	1860	6			

It should further be remembered that these systems of declination were founded on standard catalogues which are in every respect far inferior to those which can now be produced.

The second and third points are intimately connected with each other. If certainty in systematic corrections is secured, it will be at the expense of observations which might otherwise be devoted to the most proper objects.

On the other hand, when the proper standards of reference are neglected, and attention is almost wholly devoted to the determination of so-called absolute positions of stars not frequently observed, the value of the results is impaired to an enormous degree, unless determinations are made with such skill and completeness that a vast amount of labor results in a comparatively insignificant number of star positions; and even then the difficulty is but partly remedied, since the most elaborate fundamental determinations are still subject to large systematic corrections, for which, in the case we have supposed, there is no means of ascertainment by comparison. The evil which has just been described is a serious matter in the cases of several modern catalogues of declinations, and renders the material they present almost valueless in cases where great precision is required.

It is hardly necessary to say that the reflections presented in the foregoing remarks, and the conclusions which it seems justifiable to draw from them, as to the best plan of observation, are not original with me. They are in the minds of most eminent authorities on meridian work; and are, in fact, practically acted upon by them. The conclusions are;—that the work of obtaining star positions should be divided into at least three distinct operations which should never be intermingled in practical execution.

First, the determination of absolute positions for a few standard stars.

Probably the number of such stars ought not to exceed two hundred. If one aims at the highest precision, there is no problem in the whole range of practical physics which requires greater nicety of precaution as to surrounding conditions of observation, closer attention to means of measurement, more vigor in pushing those means to their ultimate limit of capability for exactitude, or more painstaking regard for the action of physical laws as well on the instruments concerned in observation as on the surrounding atmosphere,—than this which has for its object the determination of the absolute positions of the celestial bodies. If this be true, no stronger argument could be presented to show, first, that this problem is always sufficiently intricate and laborious to claim

undivided attention, and secondly, that where it does not secure this attention the results must be at least of doubtful value. If another argument were needed it would lie in the fact that the instruments best adapted for secondary, or differential observation, are not at all suitable for this research. The former purpose may require comparatively great optical power and, consequently, great dimensions in the remaining parts of the instrument.

For the best independent work a telescope of short focus and not more than four inches aperture, with interchangeable ocular and objective, is probably best adapted. For secondary work, fixity in adjustment and uniformity in use may be tolerated; but with absolute measurements we need an instrument which admits the greatest mobility in adjustment, and the greatest variety of conditions in use. Instruments of the latter class must be readily reversible. The circles should be small; and not only should they be capable of easy and accurate rotation on the cone of the axis, but it should also be possible both to rotate and interchange these cones, as well as the two halves of the telescope tube with reference to the central cube, so that from time to time they may be securely bolted in new positions. I believe that these are requirements of great importance; and they can be secured most readily in a small instrument, which, from the lightness and comparative inflexibility of its parts, is susceptible of the greatest nicety in mechanical construction, and the greatest ease and safety in subsequent changes of its principal adjustments. The ease with which observations can be made is a most decided argument in favor of small instruments, especially in this class of observations, which demands a large number of auxiliary investigations of instrumental corrections and their changes.

The observing room should be entirely detached from other buildings, and should be of the lightest practicable construction. Then, if a light roof is provided, which can be partially or entirely removed by sliding to the east or west during observation, we should be more likely to have that most desirable thing, one set of atmospheric conditions within the observing room and without.

The *second* class of operations consists in secondary observation; which involves the extension of systems, derived under the first head, to a larger number of objects, for the double purpose of determining the positions of brighter stars on account of the individual interest which many of them possess, and to furnish

a larger number of reference points to be used in zone work. Briefly, this method of observation does not imply the use of the zone plan, but is secondary in the sense that corrections to the actual results of instrumental readings are derived from a previously adopted standard catalogue, in such a manner that the application of the corrections will faithfully reproduce the system of star places originally adopted. In this first extension of fundamental systems to other stars, the zone plan would not be convenient in practice because of the fewness of stars for reference afforded by absolute determination, and because the best economy requires that the number of stars to be determined in this way should probably not much exceed 2000,—a number too small for economical division into zones. In this class of observation might also be included the stars most remarkable for proper motion, the principal variables, and a few stars interesting for other reasons. The catalogue produced by the Leipzig observatory for the mean epoch 1868 illustrates the methods implied in this system of observations.

The *third* class of operations consists in tertiary, or zone observations. These observations may be of greater or less precision according to the objects sought, but should in all cases depend upon a catalogue of standard positions. The plan of observing differences of position in narrow zones is advantageous as well in accuracy as in rapidity of work. The idea of small pretensions to accuracy has come to be attached to the mention of zone work, mainly because the purpose of those who have hitherto used the method called for observation of a large number of objects rather than for great precision in individual cases. The term zone work has really nothing to do with the number of transit wires, or microscopes used in observation, but refers rather to the manner of arranging observations. The advantages of including the work of a single night (or even of years where practicable) within belts of sky not wider than five or ten degrees, are so manifest to practical observers that I shall not waste time in proving them. The experience of those who have recently been engaged in the observation of stars down to the ninth magnitude inclusive, under the programme of the *Astronomische Gesellschaft*, shows the great superiority of the zone plan of secondary observation, both in respect to extent and accuracy of results, even when the instrumental readings are much curtailed.

It is somewhat surprising that most of the participants in this work, reading a single,—or at most two microscopes, and observing transits on three to five threads, report a degree of accuracy in the resulting co-ordinates which is often superior to that of individual determinations in the general run of our modern star catalogues. Two observers under this programme can determine the positions of one hundred stars in one clear night without great fatigue—probably with less effort than either would make in observing thirty stars, with *equal accuracy* in the ordinary miscellaneous way. In the ease and accuracy of reduction there is no comparison to be made between the two systems.

The practical objection to the universal use of the zone plan in differential observation is difficulty in constructing observing lists to meet the constant and pressing demands for star places used in field astronomy, planetary comparisons, and in special studies of proper motion. At most, these direct demands need not occupy more than four or five of the national observatories; but a judicious plan of co-operation among meridian observers would solve even this problem. Suppose, for instance, each of the participants in the zone work of the *Astronomische Gesellschaft* continues to be responsible for the observation of stars coming within its own zone; in no other way could such prompt attention and such effective as well as economical results be secured for any stars in the northern heavens, requiring immediate re-observation, as in this way. And if duplication of results be desired, it might readily be secured in the same way, for the regions already covered, as well as for the entire southern heavens; since it would be possible for any one instrument, actively employed, to attend to the needs of at least two zones five degrees in width. So far from restricting individual freedom and repressing enthusiasm by the requirements of dull routine, I believe this plan would be an incentive to the greatest activity and personal interest. Each individual of the combination would be stimulated by pride and the consciousness of forming one unit in a grand combination to do the very best possible for his share in the work, and there would doubtless stand always ready plenty of fresh and competent recruits to supply the places of the recreant, the incapable, or the unfortunate.

The advantage of such a plan to the investigator would be simply incalculable. Not only would the collection of material

for discussion be an easy task compared with what it now is; but the material itself would be abundant, homogeneous and of superior quality. It might then be advisable to make a comprehensive and reliable compilation of all that has hitherto been accomplished in meridian observation of stars, with the certainty that always, hereafter, the material for discussion of the great questions of the stellar system would be in a shape that would not, as now, work practical prohibition upon the labors of investigators.

As has been already indicated, the great objection to differential observation (where great precision is sought) has been the difficulty in constructing standard catalogues which shall be free from troublesome uncertainties, introduced mainly by the use of the older catalogues for the purpose of determining proper motions.

In Right Ascension these uncertainties have not been so important, because the ratio of ancient and modern means of observation in this co-ordinate do not show the same disparity as in the case of declinations. It is highly probable that the principal systems[2] of Right Ascension now in vogue are practically free from any trace of periodic error varying with the right ascension of stars. There still remains some uncertainty in the position of the equinox; but this is not important, and in any event will not impair the accuracy of differential work in the slightest degree, since its effect is merely to add or subtract a constant term. There are, however, troublesome systematic discordances in right ascension which depend for their value upon the order of declination of stars. They might easily, and probably do spring from the residual effects of small undetected errors in the pivots of those instruments which have furnished our standard right ascensions. But, in our best compilations, this error is without doubt small in amount and regular in its progression, so that very little harm can come to differential observation from its presence.

Recently the attention of astronomers has been called to an exceedingly important error in observed right ascensions, introduced by the modern method of chronographic registry. This error, which depends on the magnitude of the star observed, has been hitherto little considered, but was suddenly brought into

[2] "On the Right Ascensions of the Equatorial Fundamental Stars;" Simon Newcomb (Appendix III, Wash. Obs., 1870). "Förteckening öfver rektascensionerna för 103 Fundamentalstjernor;" Hugo Gylden (Stockholm, Vetensk, Ak. Förhandl., 1874). "Fundamental-Catalog für die Zonen Beobachtungen;" A. Auwers (Leipzig, 1879).

general notice through Mr. David Gill,[3] present Astronomer Royal at the Cape of Good Hope. So far as is known to me this subject has been independently investigated at Berlin, Leiden and Albany, by practical observation. At Leiden, transits registered on the chronograph are found to have a decided error depending on magnitude of the star observed. This error amounted, for one observer, to something like ˢ.03 for a decrease of one magnitude (Ast. Nach. No. 2262). The fainter stars were observed later so that their transits require a minus correction.

I have followed a similar course of investigation at the Dudley Observatory. The plan of observation was this: — wire screens were provided of varying opacity, such that, when screen *I* is placed in front of the Transit Circle object-glass, the image of the star to be observed is reduced about six magnitudes. Screen *II* produces a reduction of four magnitudes. A bright star is allowed to transit thread group "B" at full brightness. When the image is between groups "B" and "C," a screen is interposed in front of the object-glass, and the diminished image is registered over group "C" or "D." Although the thread intervals are very well determined the precaution was taken to vary the above process at alternate transits, so that in successive observations each group (of five wires) is used for each kind of transit an equal number of times. Eighty-two such sets of observation were made. Assuming that the law of correction is expressed by: —

$$x\,(M-4)+y\,(M-4)^2$$

where *M* is the magnitude, I find as the correction required by my transits, registered on the chronograph: —

$$-^{s}.009\,(M-4)\;-^{s}.0004\,(M-4)^2.$$

The value of *y* is not well determined, but I am inclined to think it has an existence.

Eye and ear observations are not apparently affected by this error depending on magnitude. Mr. Gill has already pointed out this fact as a result of his investigation of the positions of the Mars-stars, which were observed by both methods. Previous to the summer of 1878, I was without a chronograph and observed transits by the eye and ear method. These observations are only partly reduced; but a series of careful observations, by both

[3] Monthly Notices, Vol. XXXIX, December, 1878.

methods, on faint stars compared with Iris in 1877, exhibit the following table of results.

* *Mag.*	*Obs'd diff.*	*Wt.*	*Computed difference.*
	s		s
6.8	—.033	1.5	—.028
8.0	—.010	1.9	—.042
8.0	+.017	2.0	—.042
8.8	+.025	1.0	—.051
9.0	—.120	1.2	—.054
9.0	—.040	1.0	—.054
9.1	—.105	1.7	—.055
9.2	—.070	1.4	—.057
9.3	—.050	1.3	—.058
9.5	+.020	1.0	—.061
9.5	—.049	1.7	—.061
10.0	—.140	.7	—.067
10.0	—.180	1.3	—.067
Mean by weights.	s —.052		s —.052

The column "observed difference" indicates the result obtained by subtracting the seconds of right-ascension obtained through chronographic registry in 1879, from those obtained by the eye and ear method in 1878. The column "computed difference" contains the corrections derived from the formula previously given as the result of screen experiments.

These investigations open up a subject of much perplexity as to the use of modern catalogues of right ascension, which depend upon the use of the chronograph. In the present connection, they appear to call for revision of our reference catalogues of right ascension in respect to this error, though the latter is probably not highly important in these catalogues for any stars brighter than the sixth magnitude. Existing eye and ear results will serve at present for standards of comparisons in this research, until modern investigation has supplied a satisfactory substitute.

The serious defects in standard catalogues of declination have been largely due to the systematic error in Bessel's reduction of Bradley's observations; because this catalogue, almost without exception, has served as an absolute point of reference in the construction of standard catalogues. Through comparison with modern observations I have found that the declinations of the "*Fundamenta*" require the correction:

$$-''.21 + 1''.56 \text{ Sin } 2Z - 82 \text{ Sin } a - ''.24\left(\frac{28° - \delta}{10°}\right) \text{Cos } a$$

for stars south of Greenwich zenith, and:

$$-''.21 + 1''.56 \text{ Sin } 2Z + ''.05 \text{ Sin } a - ''.29 \cos a$$

for stars north of the same zenith; but from insufficiency of means these corrections can only be considered as rough approximations to the true ones.[4] Thus if we have a catalogue compiled from perfect modern observations at the epoch 1835, and carried forward to 1865 with proper motions derived from uncorrected declinations of the "*Fundamenta*," it would require the approximate correction at declination, +20°:—

$$-''.24 + ''.31 \text{ Sin } a + ''.07 \text{ Cos } a.$$

Using the Normal system of my work, already cited, I find the correction of Angelander's (Bonn) declinations for 1866 (Mean δ, +20°):

$$\text{Normal} - \text{Bonn} = -''.24 + .31 \text{ Sin } a - ''.15 \cos a$$

The Bonn declinations depend on those of the Berlin *Jahrbuch*, which, in turn, correspond approximately to the conditions above indicated. The recent Paris and Brussels declinations are similarly affected for similar reasons. Independent confirmation of this fact is furnished by recent investigations as to the latitude[5] of the Paris Observatory, which is found to vary with the season of year in which the determination is made. This may be equivalent to saying that the latitude changes with the right ascensions of the stars observed, since it depends on the declinations of a catalogue of reference. I have found[6] that the Paris Standard catalogue of declinations requires the correction,—

$$+''.21 \text{ Sin } (a - 14°)$$

If now, we suppose the average of observations at night to fall at 11h, Paris M. T., we may write for $(a - 14°)$,

$$\frac{360}{365.25}(t + 73^d)$$

where t denotes the number of days reckoned from January 1.

[4] Section VII. Appendix H, Report of U. S. Northern Boundary Commission.
[5] Comptes Rendus, LXXXVII, 686.
[6] Report of U. S. Nor. Bound. Comm., App. H, p. 129.

The *error* of the observed latitudes will then be approximately expressed by the formula: —

$$+''.21 \text{ Sin } \left[\frac{360}{365.25}(t-110^d)\right]$$

M. Gaillot finds:

$$+''.20 \text{ Sin } \left[\frac{360}{365.25}(t-95^d)\right]$$

as the error actually observed.

Happily these troublesome effects need no longer exist, since we are now able to dispense with Bradley's declinations in the formation of Normal Systems of declination,— a course already followed by me in the work cited. The declinations of the principal stars discussed in that work are predicted for the Epoch 1875.0 with an average probable error of $\pm''.07$ in the differential sense, and the proper motions with a probable error of $\pm''.002$ to $\pm''.003$. This degree of accuracy is obviously unattainable by the use of any one meridian instrument during a few years. In this connection it may not be without interest to present the results of a comparison of the declinations in question with those recently published[7] by Dr. Auwers, to serve as a standard for the participants in the zone work. The mean epoch of the authorities employed in compilation of the latter work is 1868, and the epoch of reference is 1875.0. Dr. Auwers derives more than one-half the weight of his results from authorities which were not available to me at the time of my discussion. Systematically, his declinations depend on the new Poulkowa Catalogue for 1865 — an authority not at my disposal in the formation of my normal system. The comparison will, therefore, furnish some independent means of judging the accuracy which can now be reached in predicting the declinations of stars. If we take all the stars in common (115) which are determined in my own catalogue with a probable error (for 1875.0) less than $\pm''.10$, we find the largest difference between the two to be $''.64$, and that only five differences exceed $''.50$. The mean difference without regard to sign is $''.17$; but if the differences be corrected for systematic deviations the average outstanding discrepancy becomes $''.13$, and only two differences are slightly greater than $''.50$. Assuming equal accu-

[7] Fundamental Catalog für die Zonen-Beobachtungen * * * A. Auwers, Leipzig, 1879.

racy for the two catalogues, we thus have as the average probable error of a single declination from either, ±″.08. If we take the differences for the entire number (256) compared, we find the mean discrepancy before systematic correction is used, to be ″.18, and after, ″.15. Even a portion of these small differences is due to the provisional proper motions employed by Dr. Auwers. The following tables exhibit the amount and character of the deviations when the differences are collected into groups. The number of stars in each group is prefixed to the signs.

DECLINATIONS.

Normal — Auwers.

δ	0h to 6h	6h to 12h	12h to 18h	18h to 24h
−10° to 0°	4 +″.33	1 +″.14	2 +″.17	6 +″.36
0 to +10	8 + .11	6 + .03	5 + .22	7 + .21
+10 to +20	5 + .33	8 + .16	6 + .24	10 + .23
+20 to +30	9 + .07	12 − .01	6 + .02	10 + .06
+30 to +40	10 − .01	4 + .21	11 + .04	8 − .08
+40 to +50	13 .00	6 + .05	8 − .02	10 + .14
+50 to +60	9 − .09	4 − .27	9 − .01	6 .00
+60 to +70	6 + .04	3 − .06	4 − .31	6 + .05
+70 to +80	3 − .01	2 − .20	5 − .18	4 − .10
+80 to +90	2 + .09	2 − .17	1 − .21	2 − .07

There does not appear to be any marked dependence of the residuals upon the right ascensions of the groups; and, in fact, a special discussion of groups of one hour each failed to reveal any such law. The following table represents the mean correction (N—A), with tolerable accuracy.

δ	N—A	δ	N—A
−10°	+″.30	+50	−″.03
0	+ .25	+60	− .06
+10	+ .18	+70	− .08
+20	+ .10	+80	− .10
+30	+ .04		
+40	+ .01		

The comparison of proper motions in declination is chiefly interesting as testing somewhat the peculiarities of Dr. Auwers' new reduction of Bradley's declinations, from which his proper motions are provisionally derived. The following table exhibits mean results.

PROPER MOTIONS.

δ	**	N—A	δ	**	N—A
— 10° to 0°	14	— ″.011	40° to 50°	37	— ″.006
0 to 10	26	— .015	50 to 60	28	— .003
10 to 20	29	— .010	60 to 70	19	+ .004
20 to 30	37	— .011	70 to 80	14	+ .004
30 to 40	31	— .019			

From these we can infer the systematic correction required by the new reduction of Bradley's declinations to be approximately as follows:

δ	Corr^n	δ	Corr^n
— 10°	+ 1″.5	+ 40°	+ 1″.4
0	+ 1 .6	+ 50	+ .7
+ 10	+ 1 .6	+ 60	— .3
+ 20	+ 1 .7	+ 70	— .6
+ 30	+ 1 .8	+ 80	— .6

Arranging the separate differences of proper motion in the order of right ascension, I fail to find any decided trace of a term depending on that order. All the residuals between declinations — 10° and + 80°, taken together give the resulting formulæ of correction —

$$+ ″.0016 \operatorname{Sin}(\alpha + 130°).$$

This coefficient is, however, small in relation to the probable chance errors of the separate residuals; and when the differences, continued in the same order, are separated into zones of convenient width, in the separate results we lose all support to the formula in question. It would appear, therefore, that we are indebted to Dr. Auwers for a reduction of Bradley's declinations, which is practically free from what has hitherto proved to be in its effects a very troublesome term of correction.

In the absolute sense, also, the probability of accuracy for a predicted system, depending on a large number of catalogues is now much greater than for a single actual determination, — provided the epoch of prediction be not too far removed from what is effectively the mean epoch of the compiled catalogue. The above-mentioned Normal System (from which the declinations of the American Ephemeris for 1881 are taken), for stars north of declination — 10°, corresponds almost exactly to 1847, at which time the weight is 66 on the adopted scale. To give some idea of this

scale, it will be sufficient to mention the five largest weights used in the discussion, viz.: Poulkowa 1845, Wt. 10; Leiden 1867, 8; Dorpat 1824, 5; Abo 1829, 5; Königsberg 1821, 4. No other catalogue received a weight greater than three. It is here necessary to bear in mind that these weights refer to the estimated value of the respective series as determinations of absolute declination. Now if ϵ be the probable error and p the weight of the Normal system at the epoch T, and $\frac{\epsilon}{n}$ the probable error of its annual change, we shall have for the weight, p', of the system for the epoch, T';

$$p' = \frac{p}{1+\frac{(T'-T)^2}{n^2}}$$

In the present case we have, $p = 66$; $n^2 = 256$; and $T = 1847$. Hence we have the following values of p' for the respective Epochs:—

Epoch	p'	*Estimated average probable error for zone 0° to +10°*
1847	66	± ″.025
1863	33	± .035
1875	16	± .05
1885	10	± .06
1900	5.5	± .09

Thus the probable error of the system for 1875 is twice, and in 1900 three and one-half times as great as in 1847. Yet if we grant that the original weights were correctly assigned, the weight for 1885 is still as great as that of the celebrated catalogue of Poulkowa for 1845; and even in 1900 its value is exceeded only by those of two catalogues out of twenty-seven employed. But whatever is the case it may not be amiss to repeat that to have a standard catalogue, which is to be used as the basis of secondary observation, entirely free from systematic error, is not so important as that the error in question shall not vary with abruptness at any point. The systematic error in declination of Piazzi's catalogue for 1800 varies in a manner so capricious as to leave the student always in doubt what share to attribute to chance and what to real change. The same is true in a less degree of other and more modern catalogues that might be named.

It would be an excellent thing, if, through the simultaneous action of the various astronomical societies, some one standard

catalogue could be recommended as the basis of secondary observation. It should then be the care of organized astronomy to secure re-discussion and re-observation at proper intervals, either by the adoption of standard researches and observations voluntarily made, or, failing such, by procuring special investigations for the purpose. By the use of such a catalogue a vast amount of talent now idle could be utilized. With reasonable skill in observation, an observer very much limited as to time and means, by devoting himself to a narrow zone could be sure of doing effective work; and — what is of equal or greater importance — his results would be in the best possible shape for use.

Finally, it may be charged that the foregoing remarks constitute a plea for extensive, organized co-operation among meridian observers. Such an impression, at least, I have desired to produce. The work of determining star places in the mass constitutes a distinct problem; but the labor it involves is too vast for the powers behind any one instrument, or institution. To secure in this department of work the necessary unity of plan and purpose which is essential to the successful conduct of physical observations for any special end, is the thing most needed at the present time. In the operations of the zone work under the *Astronomische Gesellschaft* we have an effective beginning. It only remains that the force of this inspiring example shall not be lost upon the astronomical public.

Determination of Solar Parallax at the Oppositions of Minor Planets. By Lewis Boss, of Albany, N. Y.

[ABSTRACT.]

The object of the paper is to show: —

First, that the best method of observation is afforded by the determination of differences of right ascension between stars and planets at large hour angles east and west of the meridian.

Second, that when asteroids approach the earth within distance unity, they furnish the best of means for determination of solar-parallax.

Third, that each year a number of small planets fulfil the required conditions, and that the number is sufficient to answer the most critical demands for accuracy in the mean result.

Experimental Determination of the Velocity of Light. By Albert A. Michelson, Master U. S. Navy.

INTRODUCTION.

In Cornu's elaborate memoir upon the determination of the velocity of light, several objections are made to the plan followed by Foucault, which will be considered in the latter part of this work. It may, however, be stated that the most important among these, was that the *deflection* was too small to be measured with the required degree of accuracy.

In order to employ this method, therefore, it was absolutely necessary that the deflection should be increased.

In November, 1877, a modification of Foucault's arrangement suggested itself, by which this result could be accomplished. Between this time and March of the following year, a number of preliminary experiments were performed in order to familiarize myself with the optical arrangements. The first experiment tried, with the revolving mirror, produced a deflection considerably greater than that obtained by Foucault.

Thus far, the only apparatus used was such as could be adapted from the apparatus in the laboratory of the Naval Academy.

At the expense of ten dollars, a revolving mirror was made, which could execute 128 turns per second. The apparatus was installed in May, 1878, at the laboratory. The distance used was 500 feet, and the deflection was about twenty times that obtained by Foucault.

These experiments[1], made under difficulties, and with very crude apparatus, gave the following.

TABLE OF RESULTS.

186,730	184,500
188,820	186,770
186,330	185,000
185,330	185,800
187,900	187,940
Mean	186,500 $\pm$ 300 miles per second.

In the following July, the sum of $2000 was placed at my disposal for carrying out these experiments on a large scale.

[1] See Proc. Am. Assoc. Adv. Science, St. Louis meeting.

Before ordering any of the instruments, however, it was necessary to find whether or not, it was practicable to use a large distance. With a distance (between the revolving and the fixed mirror) of 500 feet in the preliminary experiments, the field of light in the eye-piece, was somewhat limited, and there was considerable indistinctness in the image, due to atmospheric disturbances.

Accordingly, the same lens (39 feet focus) was employed, being placed, together with the other pieces of apparatus, along the north sea-wall of the Academy grounds; the distance being about 2000 feet. The image of the slit, at 12 M., was so confused as not to be recognizable, but towards sunset it became clear and steady and measurements were made of its position which agreed within one one-hundredth of a millimeter. It was thus demonstrated that with this distance, and a deflection of one hundred millimeters, this measurement could be made accurate to the ten-thousandth part.

In order to obtain this deflection it was sufficient to make the mirror revolve 250 times per second and to use a "radius" of about 30 feet. In order to use this large radius (distance from slit to revolving mirror), it was necessary that the mirror should be large, and optically true. Also, that the lens should be large and of great focal length. Accordingly, the mirror was made $1\frac{1}{4}$ inches in diameter; and the lens, 8 inches in diameter, with a focal length of 150 feet.

In January, 1879, an observation was taken, using the old lens, the mirror making 128 turns per second. The deflection was about 43 millimeters. The micrometer eye-piece used was substantially the same as Foucault's, except, that part of the inclined plate of glass was silvered, thus securing a much greater quantity of light. The deflection having reached 43 millimeters, the inclined plate of glass could be dispensed with, the light going past the observer's head, through the slit, and returning 43 millimeters to the left of the slit, where it could be easily observed. Thus the micrometer eye-piece is much simplified and many possible sources of error are removed.

The field was quite limited, the diameter being, in fact, but little greater, than the width of the slit. This would have proved a most serious objection to the new arrangement. With the new lens, however, this difficulty disappeared, the field being about

twenty times the width of the slit. It was expected that, with the new lens, the image would be less distinct; but the difference, if any, was small, and was fully compensated by the greater size of the field.

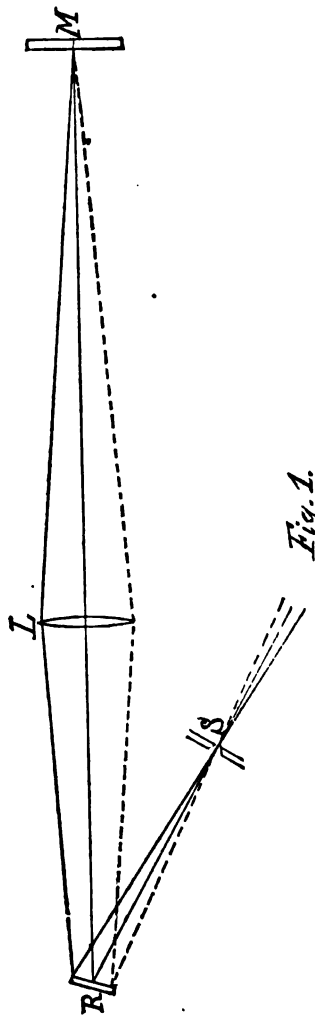


Fig. 1.

The first observation, with the new lens, was made January 30, 1879. The deflection was 70 millimeters. The image was sufficiently bright to be observed without the slightest effort. The first observation with the new micrometer eye-piece was made April 2nd, the deflection being 115 millimeters. The first of the final series of observations was made on June 5th. All the observations previous to this, thirty sets, in all, were rejected. After this time, no set of observations, nor any single observation, was omitted.

THEORY OF NEW METHOD.

Let S, Fig. 1, be a slit through which light passes, falling on R, a mirror free to rotate about an axis at right angles to the plane of the paper; L, a lens of great focal length, upon which the light falls which is reflected from R. Let M be a plane mirror whose surface is perpendicular to the line $R\ M$, passing through the centers of $R\ L$ and M, respectively. If L be so placed that an image of S is formed on the surface of M, then this image acting as the object, its image will be found at S, and will coincide point for point with S.

If now, R be turned about the axis, so long as the light falls upon the lens, an image of the slit will still be formed on the

surface of the mirror, though on a different part, and as long as the returning light falls on the lens, an image of this image will be formed at S, notwithstanding the change of position of the first image, at M. This result, namely, the production of a stationary image of an image in motion is absolutely necessary in this method of experiment. It was first accomplished by Foucault, and in a manner differing, apparently, but little from the foregoing.

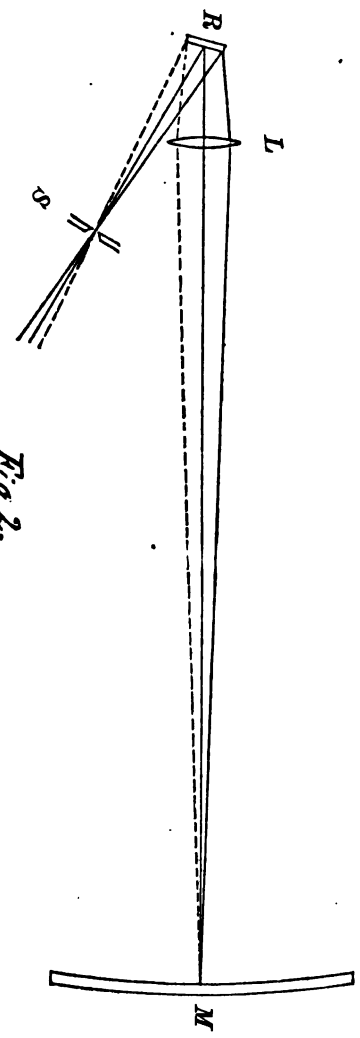


Fig. 2.

In this case L, Fig. 2, served simply to form the image of S at M, and M, the returning mirror, was spherical, the center coinciding with the axis of R. The lens, L, was placed as near as possible to R. The light forming the return image lasts, in this case, while the first image is sweeping over the face of the mirror, M. Hence, the greater the distance, $R\ M$, the larger must be the mirror, in order that the same amount of light may be preserved, and its dimensions would soon become inordinate.

The difficulty was partly met by Foucault by using five concave reflectors instead of one, but even then, the greatest distance he found it practicable to use was only 20 meters.

Returning to Fig. 1, suppose that R is in the principal focus of the lens, L; then, if the plane mirror, M, have the same diameter as the lens, the first, or moving image will remain upon

M, as long as the axis of the pencil of light remains on the lens, and *this will be the case no matter what the distance may be.*

When the rotation of the mirror, *R*, becomes sufficiently rapid, then the flashes of light which produce the second, or stationary image, become blended, so that the image appears to be continuous. But, now, it no longer coincides with the slit, but is *deflected* in the direction of rotation, and through twice the angular distance described by the mirror, during the time required for light to travel twice the distance between the mirrors. This displacement is measured by the tangent of the arc it subtends. To make this as large as possible, the distance between the mirrors, the radius, and the speed of rotation should be made as great as possible.

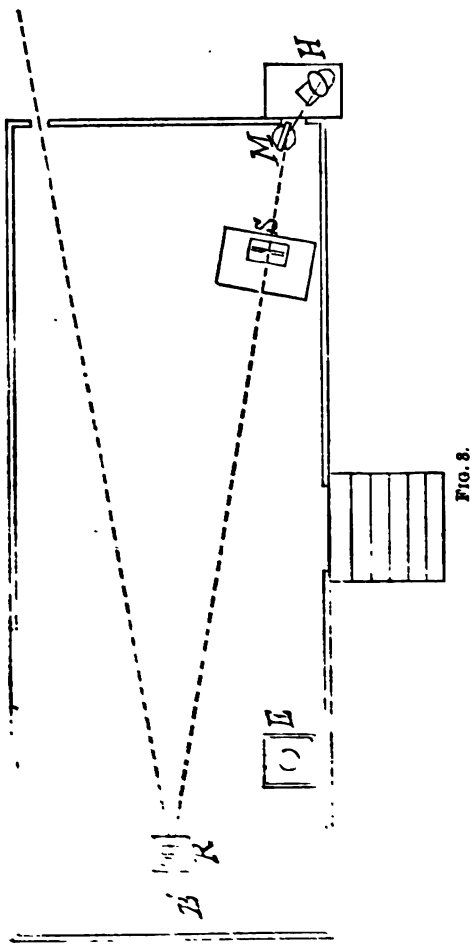


FIG. 8.

The second condition conflicts with the first, for the radius is the difference between the focal length for parallel rays, and that for rays at the distance of the fixed mirror. The greater the distance, therefore, the smaller will be the radius.

There are two ways of solving the difficulty: first, by using a lens of great focal length; and secondly, by placing the revolving mirror within the principal focus of the lens. Both

means were employed. The focal length of the lens was 150 feet, and the mirror was placed about 15 feet within the principal focus. A limit is soon reached, however, for the quantity of light received diminishes very rapidly as the revolving mirror approaches the lens.

ARRANGEMENT AND DESCRIPTION OF APPARATUS.

Site and Plan. The site selected for the experiments was a clear, almost level stretch along the north sea-wall of the Naval Academy.

A frame building was erected at the western end of the line, a plan of which is represented in Fig. 3.

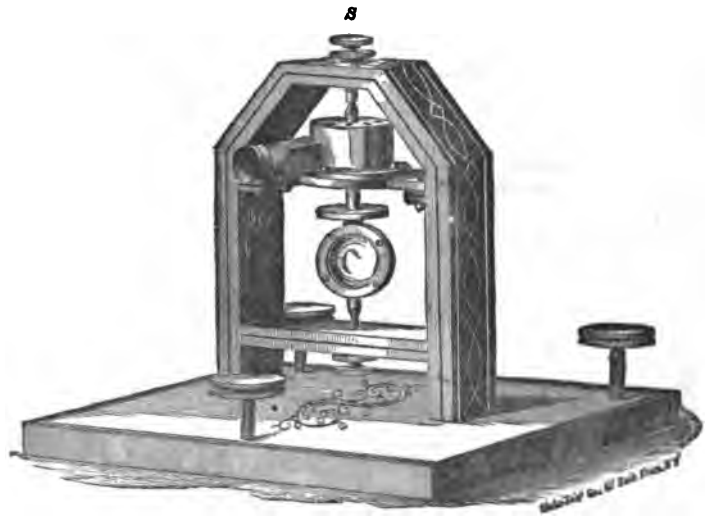


FIG. 4.

The building was 45 feet long and 14 feet wide, and raised so that the line along which the light travelled was about 11 feet above the ground. A heliostat at H reflected the sun's rays through the slit at S, to the revolving mirror, R, thence through a hole in the shutter, through the lens and to the distant mirror.

The Heliostat. The heliostat was one kindly furnished by Dr. Woodward, of the Army Medical Museum, and was a modification of Foucault's form, designed by Keith. It was found to be accurate and easy to adjust.

The light was reflected from the heliostat to a plane mirror, M, Fig. 3, so that the former need not be disturbed after being once adjusted.

The Revolving Mirror. The revolving mirror was made by Fauth & Co., of Washington. It consists of a cast iron frame resting on three levelling screws, one of which was connected by

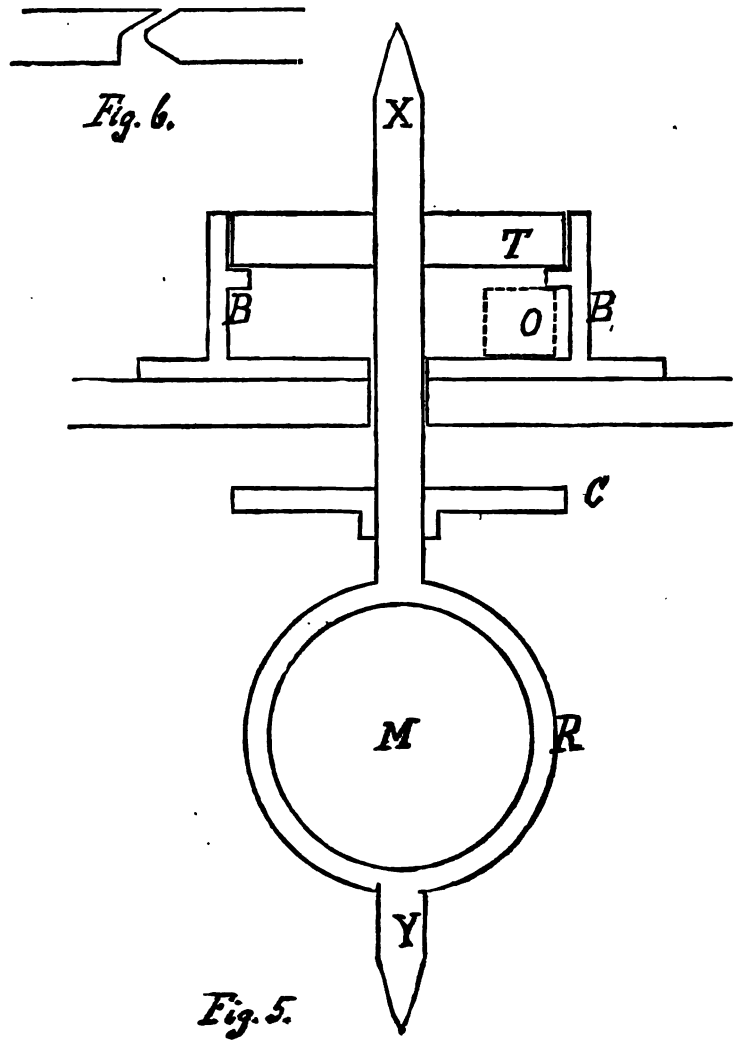


Fig. 6.

Fig. 5.

cords to the table at *S*, Fig. 3, so that the mirror could be inclined forward or backward, while making the observations.

Two binding screws, *S*, *S*, Fig. 4, terminating in hardened steel

conical sockets, hold the revolving part. This consists of a steel axle, X, Y, Fig. 5, the pivots being conical, and hardened. The axle expands into a ring at R, which holds the mirror, M.

The latter was a disc of plane glass, made by Alvan Clark & Sons, about $1\frac{1}{4}$ inch in diameter and 0.2 inch thick. It was silvered on one side only, the reflection taking place from the outer or front surface. A species of turbine wheel, T, is held on the axle by friction. This wheel has six openings for the escape of air: a section of one of them is represented in Fig. 6. The air entering on one side at O, Fig. 5, acquires a rotary motion in the box, B, B, carrying the wheel with it, and this motion is assisted by the reaction of the air in escaping.

Adjustment of the Revolving Mirror. The disc C serves the

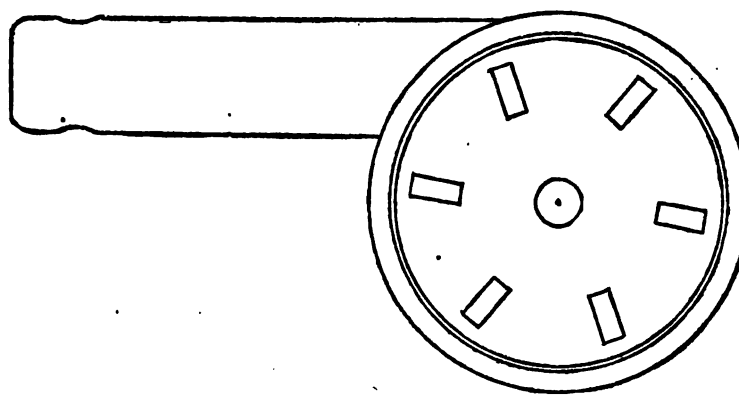


FIG. 7.

purpose of bringing the center of gravity in the axis of rotation. This was done, following Foucault's plan, by allowing the pivots to rest on two inclined planes of glass, allowing the arrangement to come to rest, and filing away the lowest part of the disc; trying again, and so on, till it would rest in indifferent equilibrium.

The part corresponding to C, in Foucault's apparatus was furnished with three vertical screws, by moving which the axis of figure was brought into coincidence with the axis of rotation. This adjustment was very troublesome. Fortunately in this apparatus it was found to be unnecessary.

When the adjustment is perfect the apparatus revolves without giving any sound, and when this is accomplished the motion is regular and the speed great. A slight deviation causes a sound

due to the rattling of the pivots in the sockets, the speed is very much diminished, and the pivots begin to wear. In Foucault's apparatus oil was furnished to the pivots, through small holes running through the screws, by pressure of a column of mercury. In this apparatus it was found sufficient to touch the pivots occasionally with a drop of oil.

Fig. 7 is a view of the turbine, box, and supply-tube, from above. The quantitity of air entering could be regulated by a

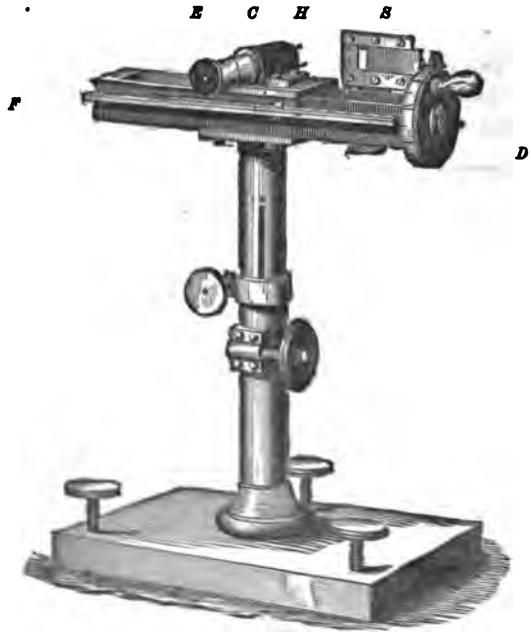


FIG. 8.

valve to which was attached a cord leading to the observer's table.

The instrument was mounted on a brick pier.

The Micrometer. The apparatus for measuring the deflection was made by Grunow of New York.

This instrument is shown in perspective in Fig. 8, and in plan by Fig. 9. The adjustable slit, S, is clamped to the frame, *F*. A long millimeter-screw, not shown in Fig. 8, terminating in the divided head, D, moves the carriage, C, which supports the eye-piece, E. The frame is furnished with a brass scale at *F*, for counting

revolutions, the head counting hundredths. The eye-piece consists of a single achromatic lens, whose focal length is about two inches.

At its focus, in H, and in nearly the same plane as the surface of the slit, is a single vertical silk fiber. The apparatus is furnished with a standard, with rack and pinion, and the base furnished with levelling screws.

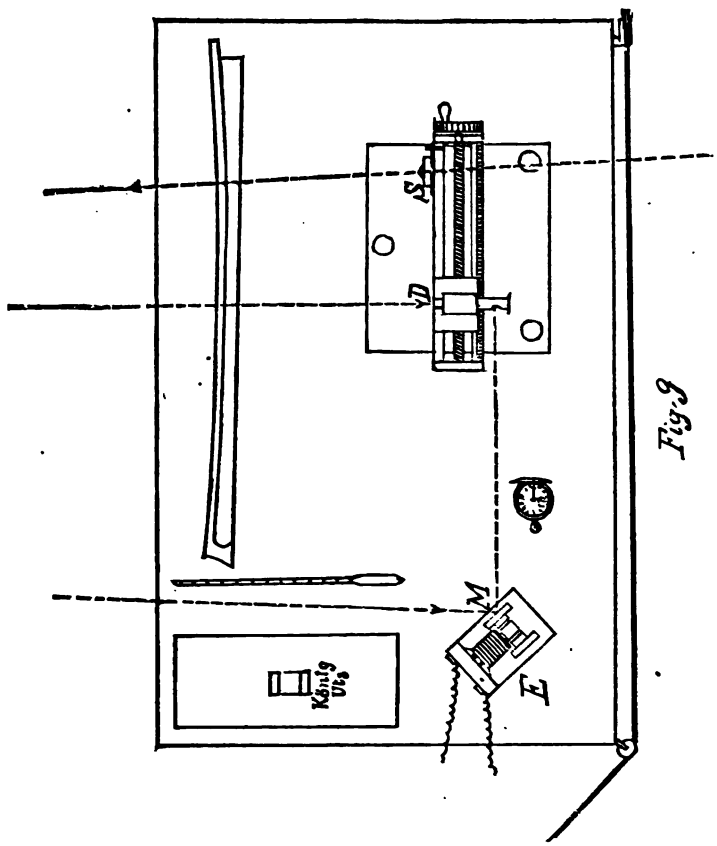
Manner of using the Micrometer. In measuring the deflection, the eye-piece is moved till the cross-hair bisects the slit, and the reading of the scale and divided head gives the position. This measurement need not be repeated unless the position or width of the slit is changed. Then the eye-piece is moved till the cross-hair bisects the deflected image of the slit; the readings of scale and head are again taken, and the difference in readings gives the deflection. The screw was found to have no lost motion, so that readings could be taken with the screw turned in either direction.

Measurement of Speed of Rotation. To measure the speed of rotation, a tuning fork, bearing on one prong a steel mirror, was used.

This was kept in vibration by a current of electricity from five "gravity" cells. The fork was so placed that the light from the revolving mirror was reflected to a piece of plane glass, in front of the lens of the eye-piece of the micrometer, inclined at an angle of 45°, and thence to the eye. When fork and revolving mirror are both at rest, an image of the revolving mirror is seen. When the fork vibrates, this image is drawn out into a band of light. When the mirror commences to revolve, the band breaks up into a number of moving images of the mirror; and when, finally, the mirror makes as many turns as the fork makes vibrations, these images are reduced to one, which is stationary. This is also the case when the number of turns is a submultiple. When it is a multiple or simple ratio, the only difference is that there are more images. Hence to make the mirror execute a certain number of turns, it is simply necessary to pull the cord attached to the valve, to the right or left, till the images of the revolving mirror come to rest.

The electric fork made about 128 vibrations per second. No dependence was placed upon this rate, however, but at each set of observations it is compared with a standard Ut_3 fork, the tem-

perature being noted at the same time. In making the comparison, the sound-beats produced by the forks were counted for 60 seconds. It is interesting to note that the electric fork, as long as it remained untouched, and at the same temperature, did not change its rate more than one or two hundredths vibrations per second.



The Observer's Table. Fig. 9 represents the table at which the observer sits. The light from the heliostat passes through the slit at *S*, goes to the revolving mirror, etc., and on its return forms an image of the slit at *D*, which is observed through the eye-piece.

E represents the electric fork (the prongs being vertical) bear-

ing the steel mirror *M*. *K* is the standard fork on its resonator. *C* is the cord attached to the valve supplying air to the turbine.

The Lens. The lens was made by Alvan Clark & Sons. It was 8 inches in diameter; focal length 150 feet; not achromatic. It was mounted in a wooden frame, which was placed on a support moving on a slide, about 16 feet long, placed about 80 feet from the building. As the diameter of the lens was so small in comparison with its focal length, its want of achromatism was inappreciable. For the same reason the effect of "parallax" (due to want of coincidence in the plane of the image with that of the silk fiber in the eye-piece) was too small to be noticed.

The Fixed Mirror. The fixed mirror was one of those used in taking photographs of the transit of Venus. It was about 7 inches in diameter, mounted in a brass frame, capable of adjustment in a vertical and a horizontal plane, by screw motion. Being prismatic, it had to be silvered on the front surface. To facilitate adjustment, a small telescope, furnished with cross-hairs, was attached to the mirror by a universal joint. The heavy frame was mounted on a brick pier, and the whole, surrounded by a wooden case, to protect it from the sun.

Adjustment of the Fixed Mirror. The adjustment was effected as follows: A theodolite was placed at about one hundred feet in front of the mirror, and the latter was moved about by the screws till the observer at the theodolite saw the image of his telescope reflected in the center of the mirror. Then the telescope attached to the mirror was pointed (without moving the mirror itself) at a mark on a piece of cardboard attached to the theodolite. Thus the line of collimation of the telescope was placed at right angles to the surface of the mirror. The theodolite was then moved to one thousand feet, and, if found necessary, the adjustment was repeated. Then the mirror was moved by the screws till its telescope pointed at the hole in the shutter of the building. The adjustment was completed by moving the mirror, by signals, till the observer, looking through the hole in the shutter through a good spy-glass, saw the image of the spy-glass reflected centrally in the mirror.

The whole operation was completed in a little over an hour.

Notwithstanding the wooden case about the pier, the mirror would change its position between morning and evening; so

that the last adjustment had to be repeated before every series of experiments.

Apparatus for supplying and regulating the blast of air. Fig. 10 represents a plan of the lower floor of the building. *E* is a three horse power Lovegrove engine and boiler, resting on a stone foundation; *B*, a small Root's blower; *G*, an automatic regulator. From this, the air goes to a delivery pipe, up through the floor, and to the turbine. The engine made about four turns per second, and the blower, about fifteen. At this speed the pressure of the air was about half a pound per square inch.

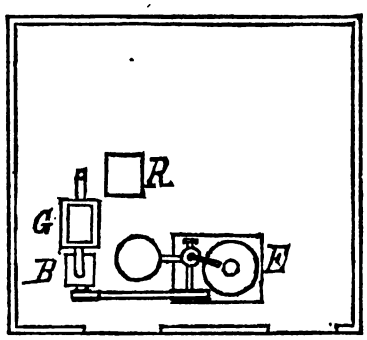


FIG. 10.

The regulator, Fig. 11, consists of a strong bellows, supporting a weight of 370 pounds, partly counterpoised by 80 pounds in order to prevent the bellows from sagging. When the pressure of air from the blower exceeds the weight, the bellows commences to rise, and in so doing, closes the valve, *V*.

This arrangement was found in practice to be insufficient, and the following addition was made: A valve was placed at *P*, and the pipe was tapped a little farther on, and a rubber tube, led to a water gauge, Fig. 12. The column of water in the smaller tube is depressed and when it reaches the horizontal part of the tube, the slightest variation of pressure sends the column from one end to the other. This is checked by an assistant at the valve; so that the column of water is kept at about the same place, and the pressure, thus rendered very nearly constant. The result was satisfactory, though not in the degree anticipated.

It was possible to keep the mirror at a constant speed for three or four seconds at a time, and this was sufficient for an observation. Still it would have been more convenient to keep it so for a longer time.

I am inclined to think that the variations were due to changes in the friction of the pivots, rather than to changes of pressure of the blast of air.

It may be mentioned that the test of uniformity was very deli-

cate, as a change of speed of one or two hundredths of a turn per second could easily be detected.

Method followed in experiment. It was found that the only time during the day when the atmosphere was sufficiently quiet

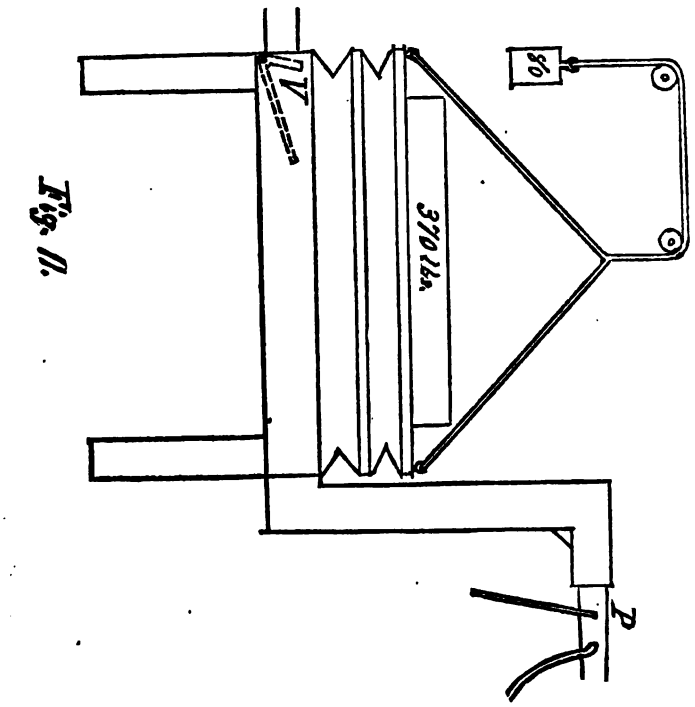


Fig. 11.

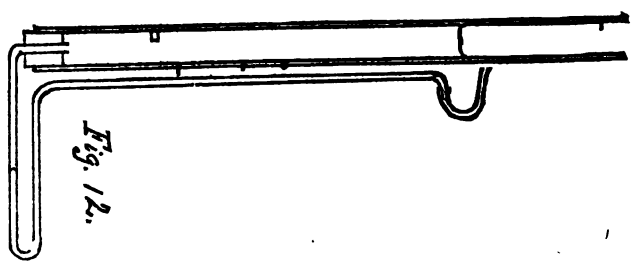


Fig. 12.

to get a distinct image was during the hour after sunrise, or during the hour before sunset. At other times the image was "boiling," so as not to be recognizable. In one experiment the electric light was used, at night, but the image was not more distinct than at sunset, and the light was not steady.

The method followed in experiment was as follows: The fire was started half an hour before, and by the time everything was ready, the gauge would show 40 or 50 pounds of steam. The mirror was adjusted by signals, as before described. The heliostat was placed and adjusted. The revolving mirror was inclined to the right or left, so that *direct* reflection of light from the slit fell either above or below the eye-piece[2].

The revolving mirror was then adjusted by being moved about, and inclined forward and backward, till the light was seen reflected back from the distant mirror. This light was easily seen through the coat of silver on the mirror.

The distance between the front face of the revolving mirror and the cross-hair of the eye-piece was then measured by stretching from one to the other a steel tape, making the drop of the catenary about an inch; as then, the error caused by the stretch of the tape, and that due to the curve, just counterbalance each other.

The position of the slit, if not determined before, was then found as before described. The electric fork was started, the temperature noted, and the standard fork counted for 60 seconds. This was repeated two or three times before every set of observations. The eye-piece of the micrometer was then set approximately[3], and the revolving mirror started. If the image did not appear, the mirror was inclined forward or backward till it came in sight.

The cord connected with the valve was pulled right or left till the images of the revolving mirror, represented by the two round bright spots to the left of the cross-hair, came to rest. Then the screw was turned till the cross-hair bisected the deflected image of the slit. This was repeated till ten observations were taken, when the mirror was stopped, temperature noted, and beats counted. This was called a set of observations. Usually five sets were taken morning and evening.

[2] Otherwise this light would overpower that which forms the image to be observed. As far as I am aware, Foucault does not speak of this difficulty. If he allowed this light to interfere with the brightness of the image, he neglected a most obvious advantage. If he did incline the axis of the mirror to the right or left, he makes no allowance for the error thus introduced.

[3] The deflection being measured by its tangent, it was necessary that the scale should be at right angles to the radius drawn from the mirror to one or the other end of that part of the scale which represents this tangent. This was done by setting the eye-piece approximately to the expected deflection, and turning the whole micrometer about a vertical axis, till the cross-hair bisected the circular field of light reflected from the revolving mirror. The axis of the eye-piece being at right angles to the scale, the latter would be at right angles to radius drawn to the cross-hair.

DETERMINATION OF THE CONSTANTS.

Comparison of the steel tape with the Standard Yard. The steel tape used was one of Chesterman's, 100 feet long. It was compared with Wurdemann's copy of the standard yard, as follows: Temperature was 55° Fahr.

The standard yard was brought under the microscopes of the comparator; the cross-hair of the unmarked microscope was made to bisect the division marked 0, and the cross-hair of the microscope marked *I*, was made to bisect the division marked 36. The reading of microscope, *I*, was taken, and the other microscope was not touched during the experiment. The standard was then removed and the steel tape brought under the microscopes and moved along till the division marked 0.1 (feet) was bisected by the cross-hair of the unmarked microscope. The screw of microscope, *I*, was then turned till its cross-hair bisected the division marked 3.1 (feet), and the reading of the screw taken. The difference between the original readings and that of each measurement was taken, care being taken to regard the direction in which the screw was turned and this gave the difference in length between the standard and each successive portion of the steel tape, in terms of turns of the micrometer screw.

To find the value of one turn, the cross-hair was moved over a millimeter scale, and the following were the values obtained.

Turns of screw of microscope, *I*, in 1 millimeter.

7.68	7.73	7.60	7.67
7.68	7.62	7.65	7.57
7.72	7.70	7.64	7.69
7.65	7.59	7.63	7.64
7.55	7.65	7.61	7.63

Mean = 7.65

Hence one turn = 0.1367 mm.

or = 0.0051 inch.

The length of the steel tape from 0.1 to 99.1 was found to be greater than 33 yards, by 7.3 turns = .96 mm. =

= +.003 feet.

Correction for temperature	= +.003 feet.
Length	= 100.000 feet.
Corrected length	= 100.006 feet.

Determination of the value of Micrometer. Two pairs of lines were scratched on one side of the slit, about 38 millimeters apart, *i. e.*, from the center of first pair to center of second pair. This distance was measured at intervals of a millimeter through the whole length of the screw, by bisecting the two pairs by the vertical silk fiber at the end of the eye-piece. With these values a curve was constructed which gave the following values for this distance which we shall call *D*.

At	0	of	scale	D,	=	38.155	turns	of	screw.
"	10	"	"	"	"	38.155	"	"	"
"	20	"	"	"	"	38.150	"	"	"
"	30	"	"	"	"	38.150	"	"	"
"	40	"	"	"	"	38.145	"	"	"
"	50	"	"	"	"	38.140	"	"	"
"	60	"	"	"	"	38.140	"	"	"
"	70	"	"	"	"	38.130	"	"	"
"	80	"	"	"	"	38.130	"	"	"
"	90	"	"	"	"	38.125	"	"	"
"	100	"	"	"	"	38.120	"	"	"
"	110	"	"	"	"	38.110	"	"	"
"	120	"	"	"	"	38.105	"	"	"
"	130	"	"	"	"	38.100	"	"	"
"	140	"	"	"	"	38.100	"	"	"

Changing the form of this table, we find that for the *first ten* turns the *average* value of *D* is 38.155

For	the	first	20	turns,	38.153
"	"	"	30	"	38.152
"	"	"	40	"	38.151
"	"	"	50	"	38.149
"	"	"	60	"	38.148
"	"	"	70	"	38.146
"	"	"	80	"	38.144
"	"	"	90	"	38.142
"	"	"	100	"	38.140
"	"	"	110	"	38.138
"	"	"	120	"	38.135
"	"	"	130	"	38.132
"	"	"	140	"	38.130

On comparing the scale with the standard meter, the temperature being 16°. 5 *C*, 140 divisions were found to = 139.462 milli-

meters. This multiplied by $(1 + .0000188 \times 16.5) = 139.505$ mm. 140 divisions were found to be equal to 140.022 turns of the screw, whence 140 turns of the screw = 139.483 millimeters.

1 " " " " = 0.996305 " "

This is the *average* value of one turn in 140.

But the average value of D, for 140 turns is, from the preceding table, 38.130.

Therefore, the true value of D, is $38.130 \times .896305$ millimeters, and the average value of one turn for 10, 20, 30, etc., turns, is found by dividing $38.130 \times .996305$ by the values of D, given in the table.

This	gives	the	value	of	a turn
for	the	first	10	turns	= 0.99570 mm.
"	"	"	20	"	= 0.99570 "
"	"	"	30	"	= 0.99573 "
"	"	"	40	"	= 0.99579 "
"	"	"	50	"	= 0.99580 "
"	"	"	60	"	= 0.99583 "
"	"	"	70	"	= 0.99589 "
"	"	"	80	"	= 0.99596 "
"	"	"	90	"	= 0.99601 "
"	"	"	100	"	= 0.99606 "
"	"	"	110	"	= 0.99612 "
"	"	"	120	"	= 0.99618 "
"	"	"	130	"	= 0.99625 "
"	"	"	140	"	= 0.99630 "

[NOTE.] The micrometer has been sent to Prof. Mayer of Hoboken, to test the screw again, and to find its value. The steel tape has been sent to Prof. Rogers of Cambridge, to find its length again.

Measurement of the Distance. Square lead weights were placed along the line, and measurements taken from the forward side of one to forward side of the next. The tape rested on the ground (which was very nearly level) and was stretched by a constant force of 10 pounds.

The correction for length of the tape (100.006) was + 0.12 feet.

To correct for the stretch of the tape, the latter was stretched with a force of 15 pounds and the change of position at intervals of 20 feet, measured by a millimeter scale.

At	100	feet	the	stretch	was	8	millimeters.
"	80	"	"	"	"	5	"
"	60	"	"	"	"	5	"
"	40	"	"	"	"	3.5	"
"	20	"	"	"	"	1.5	"
	300					23.00	

Weighted mean = 7.7 "
For 10 pounds, stretch = 5.1 "
= 0.0167 feet.
Correction for whole distance = + 0.33 "

The following are the values obtained from five separate measurements:

	1985.13 feet	Allowance made in each
	1985.17 "	case for effect of tem-
	1984.93 "	perature.
	1985.09 "	
	1985.09 "	
Mean =	1985.082 "	
	+.70	Cap of pier to revolving mirror.
	+.33	Cor. for stretch of tape.
	+.12	" " length " "
	1986.23	True distance between mirrors.

Rate of Standard Ut_3 Fork. The rate of the standard Ut_3 fork was found at the Naval Academy, but as so much depended on its accuracy another series of determinations of its rate was made together with Prof. Mayer at the Hoboken Institute of Technology.

First determination. The fork was armed with a tip of copper foil, which was lost during the experiments and replaced by one of platinum having the same weight, 4.6 mgr. The fork, on its resonator, was placed horizontally, the platinum tip just touching the lamp-blacked cylinder of a Schultze chronoscope. The time was given either by a siderial break-circuit chronometer, or by the

break-circuit pendulum of a mean-time clock. In the former case, the break-circuit worked a relay which interrupted the current from three Grove cells. The spark from the secondary coil of an inductorium was delivered from a wire near the tip of the fork. Frequently two sparks near together were given, in which case the first alone was used. The rate of the chronometer, the record of which was kept at the Observatory, was very regular, and was found by observations of transits of stars during the week to be + 1.3 seconds per day, which is the same as the recorded rate.

Specimen of a determination of Rate of Ut_3 fork.

	July 4, 1879.		Temp. = 27°C.
1	0.1	2552.0	Column 1 gives the number of the spark or the number of the second.
2	255.3	2551.7	
3	510.5	2551.9	
4	765.6	2551.9	Column 2 gives the number of sinuosities or vibrations at the corresponding second.
5	1020.7	2552.1	
6	1275.7	2552.0	
7	1530.7	2551.8	
8	1786.5	2551.4	Column 3 gives the difference between 1 and 11, 2 and 12, 3 and 13, etc.
9	2041.6	2551.7	
10	2297.0	2551.5	
11	2552.1	255.180	Mean ÷ 10.
12	2807.0	+ .669	= Reduction for mean time.
13	3062.4	+ .003	= Correction for rate.
14	3317.5	+ .187	= Correction for temperature.
15	3572.8	256.069	= No. of vibrations per second.
16	3827.7		at 65° Fahr.
17	4082.5		
18	4335.9		
19	4593.3		
20	4848.5		

The correction for temperature was found by Prof. Mayer by counting the sound beats between the standard and another Ut_3 fork, at different temperatures. His result is + .012 vibrations per

second, for a diminution of 1° Fahr. Using the same method I arrived at the result + .0125. Adopted + .012.

Résumé of first Determination. In the following table, the first column gives the date, the second gives the total number of seconds, the third gives the result uncorrected for temperature, the fourth gives the temperature centigrade, the fifth gives the final result, and the sixth, the difference between the greatest and least values.

July	4	20	255.882	27.0	256.069	0.07
"	5	19	255.915	26.4	256.089	0.05
"	5	18	255.911	26.0	256.077	0.02
"	6	21	255.874	24.7	256.012	0.13
"	6	9	255.948	24.8	255.087	0.24
"	7	22	255.938	24.6	256.074	0.05
"	7	21	255.911	25.3	256.061	0.04
"	8	20	255.921	26.6	256.100	0.02
"	8	20	255.905	26.6	256.084	0.06
"	8	20	255.887	26.6	256.066	0.03
					Mean = 256.072	

In one of the preceding experiments, I compared the two Ut_8 forks, while the standard was tracing its record on the cylinder, and also while it was in position as for use in the observations. The difference, if any, was less than .01 vibration per second.

Second Determination. Joint work with Professor A. M. Mayer, Stevens Institute, Hoboken.

The fork was wedged into a wooden support, and the platinum tip allowed to rest on lampblacked paper, wound about a metal cylinder which was rotated by hand. Time was given by a break-circuit clock, the rate of which was ascertained by comparisons with Western Union Time Ball to be 9.87 sec. The spark from secondary coil of the inductorium passed from the platinum tip, piercing the paper. The size of the spark was regulated by resistances in primary circuit. The following is a specimen determination.

Column 1 gives the number of the spark or the number of seconds. Column 2 gives the corresponding number of sinuosities

or vibrations. Column 3 gives the difference between the 1st and 7th ÷ 6, 2nd and 8th ÷ 6, etc.

1	0.3	255.83
2	256.1	255.90
3	511.7	255.90
4	767.9	255.93
5	1023.5	255.92
6	1289.2	256.01
7	1535.3	255.95
8	1791.5	255.920 = Mean
9	2047.1	—.028 = Cor. for rate
10	2303.5	255.892
11	2559.0	+.180 = Cor. for temp.
12	2825.3	256.072 = No. of vib. per sec.
13	3071.0	at 65° F.

In the following résumé, column 1 gives the number of the experiments; column 2 gives the total number of seconds; column 3 gives the results not corrected for temperature; column 4 gives the temperature Fahrenheit; column 5 gives the final result; column 6 gives the difference between the greatest and least values.

1	13	255.892	80	256.072	0.18
2	11	255.934	81	256.126	0.17
3	13	255.899	81	256.091	0.12
4	13	255.988	75	256.108	0.13
5	11	255.948	75	256.068	0.05
6	12	255.970	75	256.090	0.05
7	12	255.992	75	256.112	0.20
8	11	255.992	76	256.124	0.03
9	11	255.888	81	256.080	0.13
10	13	255.878	81	256.070	0.13
			Mean =	256.094	

Effect of Support and of Scraping. The standard Ut_3 fork held in its wooden support was compared with another fork on a resonator loaded with wax and making with standard about five

beats per second. The standard was free from the cylinder. The beats were counted by coincidences with the $\frac{1}{5}$ second beats of a watch.

Specimen. Coincidences were marked

at 32 sec.
" 39 "
" 43.5 "
" 49 "
" 54.5 "
" 61.5 "

$61.5 - 32 = 29.5$
$29.5 \div 5 = 5.9$ = time of one interval between coincidences

RÉSUMÉ.

1	5.9
2	6.2
3	6.2
4	6.2

Mean = 6.13 = time of one interval between coincidences. In this time, the watch makes $6.13 \times 5 = 30.65$ beats, and the forks make $30.65 + 1 = 31.65$ beats.

Hence the number of beats per second is $31.65 \div 6.13 = 5.163$.

Circumstances the same as in last case, except that standard Ut_3 fork was allowed to trace its record on the lampblacked paper, as in finding its rate of vibration.

Specimen. Coincidences were marked at

59 seconds
4 "
10.5 "
17 "

$77 - 59 = 18$
$18 \div 3 = 6.0$ = time of one interval.

RÉSUMÉ.

No. 1	6.0	seconds	
2	6.0	"	$6.31 \times 5 = 31.55$
3	6.7	"	$+ 1.00$
4	6.3	"	32.55
5	6.5	"	$32.55 \div 6.31 = 5.159$
6	6.7	"	with fork free, 5.163
7	6.0	"	Effect of scrape $= -.004$
Mean =	6.31		

Circumstances as in first case except that both forks were on their resonators.

Specimen. Coincidences were observed at

21 seconds.
28 "
36 " $60 - 21 = 39$
44 " $39 \div 5 = 7.8$ = time of one interval
51 "
60 "

RÉSUMÉ.

No. 1	7.8 seconds.	$7.42 \times 5 =$	37.10
2	7.1 "		+ 1.00
3	7.6 "		
4	7.4 "		38.10
5	7.2 "	$38.10 \div 7.42 =$	5.133
		(above)	5.159
Mean	7.42 seconds		
Effect of support and scrape =			—.026

Mean of second determination was	256.094
Applying correction (scrape, etc.)	—.026
Corrected mean	= 256.068
Result of first determination	= 256.072
Final value	= 256.070

[NOTE.] The result of first determination excludes all work except the series commencing July 4th. If previous work is included, and also the result first obtained by Prof. Mayer, the result would be 256.089.

256.180
256.036
256.072
256.068

Mean = 256.089

The previous work was omitted on account of various inaccura-

cies, and want of practice, which made the separate results differ widely from each other.

THE FORMULÆ.

The formulæ employed are

$$(1)\ tan\ \varphi = \frac{d_1}{r}$$

$$(2)\ V = \frac{2592000'' \times D \times n}{\phi''}$$

φ = angle of deflection.
d_1 = corrected displacement (linear).
r = radius of measurement.
D = twice the distance between the mirrors.
n = number of revolutions per second.
a = inclination of plane of rotation.
d = deflection as read from micrometer.
B = number of beats per second between electric Ut_2 fork and standard Ut_2.
$Cor.$ = correction for temperature of standard Ut_2.
V = Velocity of light.
T = Value of one turn of screw. (Table Page 141). Substituting for d its value or $d \times T \times sec\ a$, ($log\ sec\ a = .00008$) and for D its value 3972.46, and reducing to kilometers, the formulæ become

$$(3)\ tan\ \varphi = c_1 \frac{dT}{r} \qquad log\ c_1 = .51607$$

$$(4)\ V = c \frac{n}{\phi} \qquad log\ c = .49670$$

D and r are expressed in feet, and d, in millimeters.
Ut_2 fork makes 256,070 vibrations per second at 65° Fahr.
$D = 3972.46$ feet.
$tan\ a$ = tangent of angle of inclination of plane of rotation = 0.02 in all but the last twelve observations, in which it was 0.015
$log\ c_1 = 51607$ (51603 in last twelve obs.)
$log\ c = 49690$.
The electric fork makes $\frac{1}{2}$ (256.070 + B + $cor.$) vibrations per second, and n is a multiple, submultiple, or simple ratio of this.

OBSERVATIONS.

Specimen Observation.
June 17th. Sunset. Image good, best in column (4).

The columns are sets of readings of the micrometer for the deflected image of slit.

	112.81	112.80	112.83	112.74	112.79
	.81	.81	.81	.76	.78
	.79	.78	.78	.74	.74
	.80	.75	.74	.76	.74
	.79	.77	.74	.76	.77
	.82	.79	.72	.78	.81
	.82	.73	.76	.78	.77
	.76	.78	.81	.79	.75
	.83	.79	.74	.83	.82
	.78	.73	.76	.78	.82
Mean =	112.801	112.773	112.769	112.772	102.779
Zero =	0.260	0.260	0.260	0.260	0.260
d =	112.541	112.513	112.509	112.512	112.519
Temp. =	77°	77°	77°	77°	77°
B =	+ 1.500				
Cor. =	− .144				
	+ 1.365				
	256.070				
n =	257.426	257.43	257.43	257.43	257.43
r =	28.157	28.157	28.157	28.157	28.157

The above specimen was selected, because in it the readings were all taken by another and noted down without divulging them till the whole five sets were completed.

The following is the calculation for V:

	1st set	2nd, 3rd, and 4th sets	5th set.
$\log c_1$ =	51607	51607	51607
" T =	99832	99832	99832
" d =	05131	05119	05123
	56570	56558	56562
" r =	44958	44958	44958
" $\tan \varphi$ =	11612	11600	11604
" φ =	2694″.7	2694″.1	2694″.3
" c =	49670	49670	49670
" n =	41066	41066	41066
	90736	90736	90736
" φ =	43052	43042	43046
" V =	47684	47694	47690
" V =	299800	299880	299850

Date.	Distinctness of image.	Temperature Fahrenheit.	Position of deflected image.	Position of slit.	Displacement of image in divisions.	Difference between greatest and least values.	B.	Cor.	Number of revolutions per second.	Radius of measurement in feet.	Value of one turn of the screw.	Velocity of light in air, in kilometers.	Remarks.
June 5th.	3	76	114.85	0.300	114.55	0.17	+1.428	−0.168	257.36	28.672	0.99614	299850	Electric light.
7th.	2	72	114.64	0.074	114.56	0.10	1.538	−0.084	257.52	28.656	0.99614	299740	P.M. Frame inclin'd.
"	2	72	114.58	0.074	114.50	0.08	1.538	−0.084	257.52	28.647	0.99614	299900	at var. angles.
"	2	72	85.91	0.074	85.84	0.12	1.533	−0.084	193.14	28.647	0.99598	300070	" " "
"	2	72	85.97	0 074	85.89	0.07	1.538	−0.084	193.14	28.650	0.99608	299930	" " "
"	2	72	114.61	0.074	114.53	0.07	1.538	−0.084	257.42	28.650	0.99614	299850	" " "
9th.	3	83	114.54	0.074	114.47	0.07	1.538	−0.216	257.39	28.658	0.99614	299850	P.M. " "
"	3	88	114.54	0.074	114.46	0.10	1.538	−0.216	257.39	28.656	0.99614	299980	" " "
"	3	83	114.54	0.074	114.47	0.08	1.538	−0.216	257.39	28.662	0.99614	299980	" " "
"	3	83	114.57	0.074	114.50	0.08	1.533	−0.216	257.39	28.660	0.99614	299980	" " "
"	2	83	114.61	0.074	114.53	0.13	1.538	−0.216	257.39	28.678	0.99614	300000	P.M.
10th.	2	90	114.60	0.074	114.52	0.11	1.517	−0.300	257.29	28.685	0.99614	299980	"
"	2	90	114.63	0.074	114.54	0.08	1.517	−0.300	257.29	28.685	0.99614	299980	A.M.
12th.	2	71	114.81	0.074	114.74	0.09	1.450	−0.073	257.45	28.690	0.99614	299650	"
"	2	71	114.78	0.074	114.70	0.05	1.450	−0.073	257.45	28.690	0.99614	299760	"
"	1	71	114.76	0.074	114.68	0.09	1.450	−0.073	257.45	28.690	0.99614	299810	"
13th.	3	79	113.64	0.074	113.55	0.09	1.500	−0.084	257.49	28.173	0.99614	300000	"
"	3	79	113.63	0.074	113.56	0.10	1.500	−0.084	257.49	28.173	0.99614	300000	"
"	2	79	113.65	0.074	113.57	0.08	1.500	−0.084	257.49	28.173	0.99614	299960	P.M.
15th.	3	79	113.63	0.960	113.55	0.06	1.517	−0.168	257.42	28.178	0.99614	299960	"
"	3	79	113.63	0.960	113.56	0.13	1.517	−0.168	257.42	28.178	0.99614	299969	"
"	3	79	113.68	0.960	113.57	0.07	1.517	−0.168	257.42	28.178	0.99614	299940	"
"	3	79	113.63	0.960	113.56	0.06	1.517	−0.168	257.42	28.178	0.99614	299960	"
"	3	79	113.63	0.960	113.57	0.11	1.517	−0.168	257.42	28.178	0.99614	299940	Set micrometer, and counted (oscillations).
"	3	79	113.41	0.960	113.15	11*	1.517	−0.168	258.70	28.159	0.99614	299980	

DATE.	Distinctness of image.	Temperature Fahrenheit.	Position of deflected image.	Position of slit.	Displacement of image in divisions.	Differences between greatest and least values.	B.	Cor.	Number of revolutions per second.	Radius of measurement	Value of one turn of the screw.	Velocity of light in air, in kilometers.	REMARKS.
June 13th.	3	79	112.14	0.260	111.88	6*	+1.517	—0.168	255.69	28.152	0.99614	299800	oscillations of image of revolving mirror.
14th.	1	64	112.83	0.260	112.57	0.12	1.500	+0.012	257.58	28.152	0.99614	299850	A. M.
"	1	64	112.83	0.260	112.57	0.05	1.517	+0.012	257.60	28.152	0.99614	299880	"
"	1	65	112.81	0.260	112.55	0.11	1.517	0.000	257.59	28.152	0.99614	299900	"
"	1	66	112.83	0.260	112.57	0.09	1.517	—0.012	257.57	28.152	0.99614	299840	"
"	1	67	112.83	0.260	112.57	0.12	1.517	—0.024	257.56	28.152	0.99614	299830	"
14th.	1	84	112.78	0.260	112.52	0.06	1.517	—0.228	257.36	28.159	0.99614	299790	P. M. Readings taken by
"	1	85	112.76	0.260	112.50	0.08	1.500	—0.240	257.33	28.159	0.99614	299810	" Lieut. Nazro.
"	1	84	112.72	0.260	112.46	0.08	1.483	—0.228	257.32	28.159	0.99614	299880	" " "
"	1	84	112.73	0.260	112.47	0.09	1.483	—0.228	257.32	28.159	0.99614	299880	"
"	1	84	112.75	0.260	112.49	0.09	1.483	—0.228	257.32	28.159	0.99614	299830	"
17th.	2	62	112.85	0.260	112.59	0.09	1.517	+0.036	257.62	28.149	0.99614	299800	A. M.
"	2	63	112.84	0.260	112.58	0.06	1.500	+0.024	257.59	28.149	0.99614	299790	"
"	1	64	112.85	0.260	112.59	0.07	1.500	+0.012	257.58	28.149	0.99614	299760	"
17th.	3	77	112.80	0.260	112.54	0.07	1.500	—0.144	257.43	28.157	0.99614	299800	P. M. Readings taken by
"	3	77	112.77	0.260	112.51	0.06	1.500	—0.144	257.43	28.157	0.99614	299880	" Mr. Clason.
"	3	77	112.77	0.260	112.51	0.11	1.500	—0.144	257.43	28.157	0.99614	299880	" " "
"	3	77	112.77	0.260	112.51	0.09	1.500	—0.144	257.43	28.157	0.99614	299880	" " "
"	3	77	112.78	0.260	112.52	0.06	1.500	—0.144	257.43	28.157	0.99614	299860	" " "
18th.	1	58	112.90	0.265	112.64	0.07	1.500	+0.084	257.65	28.150	0.99614	299720	A. M.
"	1	58	112.90	0.265	112.64	0.10	1.500	+0.084	257.65	28.150	0.99614	299720	"
"	1	59	112.92	0.265	112.66	0.07	1.483	+0.072	257.62	28.150	0.99614	299620	"
18th.	2	75	112.79	0.265	112.52	0.09	1.483	—0.120	257.43	28.158	0.99614	299860	P. M.
"	2	75	112.75	0.265	112.48	0.10	1.483	—0.120	257.43	28.158	0.99614	299970	"
"	2	75	112.76	0.265	112.49	0.08	1.483	—0.120	257.43	28.158	0.99614	299950	"

DATE.	Distinctness of image.	Temperature Fahrenheit.	Position of deflected image.	Position of slit.	Displacement of image, in divisions.	Difference between greatest and least values.	B.	Cor.	Number of revolutions per second.	Radius of measurement in feet.	Value of one turn of the screw.	Velocity of light in air, in kilometers.	REMARKS.
June 20th.	3	60	112.94	0.265	112.67	0.07	+1.517	+0.063	257.65	33.173	0.99614	299880	A. M.
"	3	61	112.92	0.265	112.65	0.09	1.517	+0.048	257.63	33.173	0.99614	299910	"
"	2	62	112.94	0.265	112.67	0.07	1.517	+0.036	257.62	33.173	0.99614	299850	"
"	2	65	112.93	0.265	112.66	0.06	1.517	+0.024	257.61	33.173	0.99614	299870	"
"	2	78	133.45	0.265	133.21	0.13	1.450	—0.156	257.36	33.345	0.99637	299840	P. M.
"	2	79	133.49	0.265	133.23	0.09	1.500	—0.168	257.40	33.345	0.99637	299840	"
"	2	80	133.49	0.265	133.23	0.07	1.500	—0.180	257.39	33.345	0.99637	299850	"
"	2	79	133.50	0.265	133.24	0.13	1.483	—0.168	257.39	33.345	0.99637	299840	"
"	2	79	133.49	0.265	133.23	0.06	1.483	—0.168	257.38	35.345	0.99637	299840	"
"	2	79	133.49	0.265	133.23	0.10	1.483	—0.168	257.38	33.345	0.99637	299840	"
21st.	3	61	133.56	0.265	133.29	0.12	1.533	+0.048	257.65	33.333	0.99637	299800	A. M.
"	3	62	133.58	0.265	133.31	0.03	1.533	+0.036	257.64	33.333	0.99637	299810	"
"	3	65	133.57	0.265	133.31	0.09	1.533	+0.024	257.63	33.333	0.99637	299810	"
"	3	64	133.57	0.265	133.30	0.11	1.533	+0.012	257.61	33.333	0.99637	299820	"
"	3	65	133.56	0.265	133.30	0.13	1.533	0.000	257.60	33.333	0.99637	299800	"
"	3	80	133.45	0.265	133.21	0.06	1.533	—0.180	257.43	33.330	0.99637	299770	P. M.
"	3	81	133.46	0.265	133.19	0.10	1.500	—0.192	257.38	33.330	0.99637	299760	"
"	3	82	133.46	0.265	133.20	0.05	1.500	—0.204	257.37	33.330	0.99637	299740	"
"	3	82	133.46	0.265	133.20	0.08	1.517	—0.204	257.38	33.330	0.99637	299750	"
"	3	81	133.46	0.265	133.19	0.08	1.500	—0.192	257.38	33.330	0.99637	299760	"
23rd.	3	80	133.43	0.265	133.16	0.08	1.543	—0.288	257.33	33.345	0.99637	299910	P. M.
"	3	80	133.43	0.265	133.15	0.06	1.550	—0.288	257.33	33.345	0.99637	299890	"
"	3	90	133.45	0.265	133.17	0.09	1.550	—0.300	257.33	33.345	0.99637	299930	"
"	3	90	133.43	0.265	133.16	0.07	1.533	—0.300	257.30	33.345	0.99637	299960	"
"	3	90	133.43	0.26 5	133.16	0.07	1.517	—0.300	257.29	33.345	0.99637	299980	"

DATE.	Distinctness of image.	Temperature Fahrenheit.	Position of deflected image.	Position of slit.	Displacement of image in divisions.	Difference between greatest and least values.	B.	Cor.	Number of revolutions per second.	Radius of measurement in feet.	Value of one turn of the screw.	Velocity of Light in air in kilometers.	REMARKS.
June 24th.	3	79	133.47	0.265	133.20	0.15	+1.517	—0.084	257.50	33.319	0.99937	299790	A. M.
"	3	73	133.44	0.265	133.17	0.04	1.517	—0.096	257.49	33.319	0.99937	299840	"
"	3	74	133.43	0.265	133.16	0.11	1.517	—0.106	257.48	33.319	0.99937	299850	"
"	3	75	133.43	0.265	133.16	0.06	1.517	—0.120	257.47	33.319	0.99937	299850	"
"	3	76	133.44	0.265	133.18	0.10	1.517	—0.133	257.45	33.319	0.99937	299780	"
26th.	2	80	133.43	0.265	133.15	0.05	1.506	—0.252	257.38	33.339	0.99937	299830	P. M.
"	2	86	133.44	0.265	133.17	0.06	1.506	—0.252	257.38	33.339	0.99937	299840	"
27th.	3	73	133.49	0.265	133.23	0.11	1.483	—0.096	257.46	33.328	0.99937	299790	A. M.
"	3	74	133.47	0.265	133.20	0.06	1.483	—0.106	257.44	33.328	0.99937	299810	"
"	3	75	133.47	0.265	133.21	0.09	1.483	—0.120	257.43	33.323	0.99937	299760	"
"	3	75	133.45	0.265	133.19	0.09	1.467	—0.120	257.43	33.328	0.99937	299810	"
"	3	76	133.47	0.265	133.20	0.08	1.483	—0.133	257.43	33.328	0.99937	299790	"
"	3	76	133.45	0.266	133.19	0.10	1.483	—0.133	257.43	33.328	0.99937	299810	"
30th.	2	85	35.33	135.00	99.68	0.05	1.500	—0.240	193.00	33.274	0.99945	299820	P. M. mirror inverted.
"	2	86	35.34	135.00	99.67	0.06	1.506	—0.252	193.00	33.274	0.99945	299850	" " "
"	2	86	35.34	135.00	99.66	0.10	1.506	—0.252	193.00	33.274	0.99945	299870	" " "
"	2	86	35.34	135.00	99.66	0.09	1.517	—0.252	193.00	33.274	0.99945	299870	" " "
July 1st.	2	83	02.17	135.145	132.98	0.07	1.500	—0.216	257.35	33.293	0.99937	299810	P. M. " "
"	2	84	02.15	135.145	133.00	0.09	1.500	—0.228	257.34	33.289	0.99937	299740	" " "
"	2	86	02.14	135.145	133.01	0.06	1.467	—0.252	257.28	33.311	0.99937	299810	" " "
"	2	86	02.14	135.145	133.00	0.08	1.467	—0.252	257.28	33.311	0.99937	299940	" " "
2nd.	3	86	99.85	0.400	99.45	0.05	1.450	—0.252	192.95	33.305	0.99806	299950	P. M. mirror erect.
"	3	86	66.74	0.400	66.34	0.03	1.450	—0.252	128.63	33.305	0.99586	299800	" " "
"	3	86	50.16	0.400	47.96	0.07	1.467	—0.252	96.48	33.305	0.99690	299810	" " "
"	3	86	33.67	0.400	33.17	0.06	1.450	—0.240	64.83	33.305	0.99674	299870	" " "

The numbers in column 2 of the preceding table are thus translated; 3 = Good, 2 = Fair, and 1 = Poor. These numbers do not, however, show the relative weights of the observations.

In the last two sets of June 13th, the micrometer was fixed at 113.41 and 112.14 respectively. The image was bisected by the cross-hair, and kept as nearly as possible in this place — mean time counting the number of seconds required for the image of the revolving mirror to complete 60 oscillations. In other words, instead of measuring the deflection, the speed of rotation was measured. In column 7 for these two sets, the numbers 11 and 6 are the differences between the greatest and the smallest number of seconds observed.

In finding the mean value of V from the table the sets are all given the same weight. The difference between the result thus obtained and that from any system of weights is small, and may be neglected.

The following table gives the result of different groupings of sets of observations. Necessarily some of the groups include others.

Electric light, (1 set)		299,850
Set micrometer, counting oscillations	(2)	299,840
Readings taken by Lt. Nazro	(3)	299,830
Readings taken by Mr. Clason	(5)	299,860
Mirror inverted	(8)	299,840
Speed of rotation, 192	(7)	299,990
Speed of rotation, 128	(1)	299,800
Speed of rotation, 96	(1)	299,810
Speed of rotation, 64	(1)	299,870
Radius, 28 5 feet	(54)	299,870
Radius, 33.3 feet	(46)	299,830
Highest temperature, 90° Fahr.	(5)	299,910
Mean of lowest temp's 60° Fahr.	(7)	299,800
Image, good.	(46)	299,860
Image, fair	(39)	299,860
Image, poor	(15)	299,810
Frame, inclined	(5)	299,960
Greatest value,		300,070
Least value,		299,650
Mean value,		299,852
Average difference from mean,		60
Value found for π		3.26
Probable error		± 5

DISCUSSION OF ERRORS.

The value of V depends on three quantities D, n, and φ. These will now be considered in detail.

The distance. The distance between the two mirrors may be in error, either by an erroneous determination of the length of the steel-tape used or by all mistakes in the measurement of the distance by the tape.

The first may be caused by an error in the copy of the standard yard, or in the comparison between the standard and the tape. An error in this copy, of .00036 inch, which, for such a copy would be considered large, would produce an error of only .00001 in the final result. Supposing that the bisections of the divisions are correct to .0005 inch, which is a liberal estimate, the error caused by supposing the error in each yard to be in the same direction, would be only .000014; or the total error of the tape, if both errors were in the same direction would be .000024 of the whole length.

The calculated probable error of the five measurements of the distance was $\pm$.000015; hence the total error due to D would be at most .00004. The tape has been sent to Prof. Rogers of Cambridge for comparison, to confirm the result.

The Speed of rotation. This quantity depends on three conditions. It is affected 1st by an error in the rate of the standard, 2nd by an error in the count of the sound beats between the forks, and 3rd by a false estimate of the moment when the image of the revolving mirror is at rest at which moment the deflection is measured. The calculated probable error of the rate is .000016. If this rate should be questioned, the fork can be again rated and a simple correction applied. The fork is carefully kept at the Stevens Institute, Hoboken, and comparisons were made with two other forks in case it was lost or injured.

In counting the sound beats, experiments were tried to find if the vibrations of the standard were affected by the other fork, but no such effect could be detected. In each case the number of beats was counted correctly to .02 or less than .0001 part, and in the great number of comparisons made this source of error could be neglected.

The error due to an incorrect estimate of the exact time when the images of the revolving mirror came to rest was eliminated

by making the measurement sometimes when the speed was slowly increasing, and sometimes when slowly decreasing. Further, this error would form part of the probable error deduced from the results of observations.

We may then conclude that the error, in measurement of n, was less than .00002.

The deflection. The angle of deflection, φ, was measured by its tangent, $(tan\ \varphi = \frac{d}{r})$; d was measured by the steel screw, and brass scale, and r, by the steel tape. The value of one turn of the screw was found by comparison with the standard meter, for all parts of the screw. This measurement including the possible error of the copy of the standard meter, I estimate to be correct to .00005 part. The instrument is at the Stevens Institute, where it is to be compared with a millimeter scale made by Prof. Rogers of Cambridge.

The deflection was read to within three or four hundreths of a turn at each observation, and this error appears in the probable error of the result.

The deflection is also affected by the inclination of the plane of rotation to the horizontal. This inclination was small and its secant varies slowly, so that any slight error in this angle would not appreciably affect the result.

The measurement of r is affected in the same way as D, so that we may call the greatest error of this measurement .00004. It would probably be less than this, as the mistakes in the individual measurements would also appear in the probable error of the result.

The measurement of φ was not corrected for temperature. As the corrections would be small they may be applied to the final result. For an increase of 1° F. the correction to be applied to the screw for unit length would be —.0000066. The correction for the brass scale would be +.0000105, or the whole correction for the micrometer would be +.000004.

The correction for the steel tape, used to measure r, would be +.0000066. Hence the correction for $tan\ \varphi$ would be —.000003 t. The average temperature of the experiments is 75°.6 F. $75.6 - 62.5 = 13.1$. $-.000003 \times 13.1 = -.00004$. Hence φ should be divided by 1.00004, or the final result should be multiplied by 1.00004. This would correspond to a correction of + 12 kilometers.

The greatest error, excluding the one just mentioned, would probably be less than .00009, in the measurement of φ.

Summing up the various errors, we find then that the total constant error in the most unfavorable case, where the errors are all in the same direction, would be .00015. Adding to this the probable error of the result .00002 we have for the limiting value of the error of the final result $= \pm .00017$. This corresponds to an error of ± 51 kilometers.

The correction for the velocity of light in vacuo is found by multiplying the speed in air by the index of refraction of air at the temperature of the experiments. The error due to neglecting the barometric height is exceedingly small. This correction in kilometers is $+ 80$.

Final result. The mean value of V from the tables is 299852

Correction for temperature	+12
Velocity of light in air	299864
Correction for vacuo	80
Velocity of light in vacuo	299944±51

The final value of the velocity of light from these experiments is then

299,940 kilometers per second,
or 186,380 miles per second.

OBJECTIONS CONSIDERED.

Measurement of the deflection. The chief objection, namely, that in the method of the revolving mirror the deflection is small, has already been sufficiently answered. The same objection, in another form is that the image is more or less indistinct. This is answered by a glance at the tables. These show that in each individual observation, the average error was only three ten-thousandths of the whole deflection.

Uncertainty of laws of reflection and refraction in media, in rapid rotation. What is probably hinted at under the above heading is that there may be a possibility that the rapid rotation of the mirror throws the reflected pencil in the direction of rotation. Granting that this is the case, the pencil first reflected from the mirror and the return pencil will both be equally affected and the resulting deflection will be the same as it would be had there been no such action.

Retardation caused by reflection. Cornu in answering the objection, that there may be an unknown retardation by reflection from the distant mirror, says that if such existed, the error it would introduce in his own work would be only $\frac{1}{5000}$ of that in Foucault's, on account of there being in his own experiments but one reflection, instead of twelve. The same reasoning shows that if this possible error made a difference of one per cent. in Foucault's work (and his result is correct within that amount), then the error would be but .00003 part in my own.

Distortion of the Revolving Mirror. It has been suggested that the distortion of the revolving mirror either by twisting or by the effect of centrifugal force might cause an error in the deflection. The only plane in which the deflection might be affected is the plane of rotation. Distortions in a vertical plane would have simply the effect of raising, lowering or extending the slit.

Again, if the *mean* surface is plane there will be no effect on the deflection, but simply a blurring of the image.

Even if there be a distortion of any kind there would be no effect on the deflection if the rays returned to the same position whence they were reflected.

The only case which remains to be considered then is that in which the light from the slit falls upon a distorted mirror and the return light upon a different portion of the same.

The effect of such an arrangement, when the revolving mirror is at rest, is simply to form two images besides the image coinciding with the slit, *one on either side of the slit:* and in the case there were more than two portions having different inclinations there would be formed as many images to correspond. If the surfaces are not plane, the only effect is to produce a distortion of the image.

As no multiplication of images was observed, and no distortion of the one image, it follows that the distortion of the mirror was too small to be noticed, and that even if it were larger, it could not affect the deflection.

The reasoning is the same when the mirror is in motion, save that all the images will be deflected in the direction of rotation.

Imperfection of the lens. It has also been suggested that, as the pencil goes through one-half of the lens and returns through the opposite half, if these two halves were not exactly similar the return image would not coincide with the slit when the mirror

was at rest. This would undoubtedly be true if we consider but one-half of the original pencil. It is evident, however, that the other half would pursue the contrary course, forming another image which falls on the other side of the slit, and that both these images would come into view, and the line midway between them would coincide with the true position.

No such effect was observed, and would be very unlikely to occur.

If the lens was imperfect, the faults would be all over the surface, and this would produce simply an indistinctness of the image.

Moreover, in the latter part of the observations the mirror was inverted, thus producing a positive rotation, whereas the rotation in the preceding sets was negative.

This would correct the error mentioned if it existed, and shows also that no constant errors were introduced by having the rotation constantly in the same direction, the results in both cases being almost exactly the same.

Periodic variations in friction. If the speed of rotation varied in the same manner in each revolution of the mirror, the chances would be that at the particular time when the reflection took place the speed would not be the same as the average speed found by the calculation. Such a periodic variation could only be caused by the influence of the frame, or the pivots. For instance, the frame would be closer to the ring which holds the mirror twice in every revolution than at other times, and the mirror would meet with more resistance here than at a position 90° from this. Or else there might be a certain position due to want of trueness of figure of the sockets which would cause a variation of friction at certain parts of the revolution.

To ascertain if there were any such variations the position of the frame was changed in azimuth in several experiments. The results were as before, showing that any such variation was too small to affect the result.

Change of speed of rotation. In the last four sets of observations the speed was lowered from 256 turns, to 192, 128, 96, and 64 turns per second. The results with these speeds were the same as with the greater speed within the limits of errors of experiment.

Bias. Finally to test the question if there were any bias in making these observations, eight sets of observations were taken

in which the readings were made by another, the results being written down without divulging them. Five of these sets are given in the "specimen," page 149.

It remains to notice the remarkable coincidence of the result of these experiments with that obtained by Cornu, by the method of the toothed wheel.

The result of Cornu's work as interpreted by Helmert d' Aix is 299990 kilometers.

That of these experiments is 299940 kilometers.

ON THE CONVERSION OF MECHANICAL ENERGY INTO HEAT BY DYNAMO-ELECTRIC MACHINES. By GEORGE F. BARKER, of Philadelphia, Pa.

[ABSTRACT.]

THE amount of heat actually obtainable from dynamo-electric machines when worked upon a commercial scale, is a question which in the near future is to become of very considerable commercial importance. That electric distribution, at least in our larger cities, is ultimately to be the source of light-supply, is already placed beyond a peradventure. But far more than simple light-production is to be expected of this marvellous agent. It must not only light our houses, but it must warm them, and must furnish mechanical power to them for a thousand petty operations, now either done not at all, or done by manual labor. It must pump the water, raise the elevator, run the sewing machine, turn the spit, perform its part of the laundry service and perhaps even assist in the cooking. The problem next in course of solution, after that of lighting, is that of heating by electricity. Since the energy of an electric current is always dissipated as heat, the only condition required is the localization of the resistance in the circuit where the heat is to be produced; so that instead of being diffused over the circuit, it shall be localized where it is needed. If, for example, a coil of wire of high resistance be placed in the circuit of a dynamo-electric machine the greater portion of the heat into which the current is converted appears in this coil which becomes consequently a source of heat for warming the

surrounding medium. Of course, a house may be heated electrically by either direct or indirect means. That is, the heating coil itself may be placed in the apartment to be warmed, or the current may be employed to heat air or water, which is then circulated as the source of heat. It is to this latter mode of heating that Sir William Thomson has referred, in his testimony in May last before the "Select Committee of Parliament to authorize Corporations or Gas Companies to supply Light by Electricity." He says; "I look forward to the Falls of Niagara being extensively used for the production of light and mechanical power over a large area of North America." To transmit the electric energy he suggests the use of tubular conductors through which a current of water flows to keep them cool, and remarks that the size of the copper tubes required to convey this immense power would need to be only three or four inches in diameter and of moderate thickness. Indeed, he adds, it might be economical, by diminishing the thickness of the conductor, to allow its temperature to rise, and in this way to distribute hot water through the streets of a city.

The experiments detailed in the present paper were undertaken in order to ascertain the percentage of useful effect realizable as heat from an electric current of known strength, under ordinary commercial conditions. The dynamo-electric machine used for this purpose was made by Siemens Brothers of London and is known as their "B" machine. The diameter of the driving pulley was eight inches, and its face was three inches. The resistance of the machine itself, at rest, was 0.68 ohm. Water power was used to drive it, the speed being varied from 560 to 840 revolutions per minute. The lower speeds in general were obtained with a belt one and a quarter inches wide, the intermediate ones with a belt two inches wide, and the higher ones, especially where the external resistance was low, with a three and a half inch belt. In the circuit of this machine were included a double coil tangent galvanometer, a heating coil of german silver wire, and the conducting wires. The coils of the galvanometer were single turns of very large copper wire, offering no appreciable resistance. Its constant was 5.7 webers per second as determined by Professor Farmer. The german silver wire used on the heating coils was 0.035 inch in diameter. It was wound in grooves cut on the surfaces of wooden cylinders, the lengths gradually increasing so as to give resistance varying from 0.2 ohm up to 6.84 ohms.

The conducting wires, which were of copper, were of large size; so that together with the galvanometer, their resistance was 0.05 ohm. The calorimeter employed consisted simply of a large glass battery jar, in which was put the water to be heated. The temperature was noted by means of a thermometer, graduated in Fahrenheit degrees.

The plan of operations was as follows: — A quantity of water — usually ten pounds — was weighed into the calorimeter, the heating coil was introduced, the temperature was noted, and the machine was started, the time being taken. Each experiment was usually continued five minutes, during which interval the speed of the machine was counted two or three times, and the galvanometer deflection several times observed. At the end of the time, the machine was stopped, the water well agitated, and the temperature again noted. From the data thus obtained the current strength and the evolved heat could be calculated. No attempt was made to measure the power consumed by the machine, because in the first place, no suitable dynamometer was at hand; and in the second, the object in view was not so much to ascertain the efficiency of the machine as to find out what fraction of the current-strength was actually converted into heat by means of the immersed resistance coils. Moreover the experiments of Hopkinson have shown that 87 per cent of the power applied to this machine appears as electrical energy in the circuit. Consequently the power consumed to produce a given current-strength is readily calculated, if the latter value be known.

The first series of five experiments was made under essentially similar conditions, except that the resistance of the heating coil was gradually increased. Ten pounds of water was used in the calorimeter, and the machine was driven by the $3\frac{1}{2}$ inch belt. The following are the experimental data obtained: —

No.	*Speed.*	*Resistance.*		*Deflection.*[1]	*Temperature.*	*Time.*
	Revolutions per minute.	Heating Coil. (Ohms.)	Total. (Ohms.)		(Degrees F.)	Minutes.
1.	690	0.204	0.934	87°+	76°— 82°	2
2.	840	0.310	1.049	87°	81°— 82°	2
3.	820	0.420	1.150	86.5°	80°— 128°	5
4.	840	0.610	1.340	86°	77°— 132°	5
5.	840	1.080	1.810	83.5°	81°— 130°	5

[1] It would doubtless have been better to shunt the galvanometer in these cases so as to bring its deflections nearer to 45°. The error, however, tends to make the final result too low but in no case too high.

From these figures, the final results of the experiments may be easily calculated. From the angles of deflection, we get their tangents. These, multiplied by 5.7 webers, the galvanometer constant, give us the current-strength in webers per second. This current-strength, multiplied by the total resistance of the circuit, gives us, in accordance with Ohm's formula $E = CR$, the electromotive force in volts. The product of the current-strength and the electromotive force gives the volt-webers, or current-energy; and this multiplied by 44.25 — according to the formula for work, $W = 44.25\ EC$ — gives the energy of the current in foot-pounds per minute. This may readily be reduced to horse powers. Again, multiplying the weight of water in the calorimeter by the number of degrees through which its temperature was raised, we have the total heat units — in pound-degrees Fahrenheit — produced. Dividing by the duration of the experiment in minutes, we have the heat-energy communicated to the water per minute. Multiplying this by 772, Joule's equivalent, the corresponding mechanical energy in foot pounds is obtained; and this divided by 33,000 gives the energy in horse-powers of work per minute. The following table gives these calculated results: —

No.	*Tangents.*	*Webers.*	*Volts.*	*Volt-Webers.*	*Horse-Powers.*	*Heat-Units.*	*Horse-Powers.*
1.	19.081	108.76	101.59	11048	14.82	30	0.702
2.	19.081	108.76	113.11	12302	16.12	85	1.989
3.	16.341	93.14	107.12	9976	13.38	96	2.246
4.	14.301	81.52	109.24	8905	11.94	110	2.574
5.	8.777	50.04	90.55	4530	6.09	98	2.293

Several interesting results appear from an inspection of these figures. In the first place we observe that the energy communicated to the water as heat reached its maximum in the fourth experiment, and that this maximum corresponded to 110 heat-units per minute, equivalent to 2.574 horse-powers. In the second place, since all the conditions except the resistance in the circuit remained essentially the same throughout, this maximum is clearly due to the resistance of the heating coil used in that experiment. This resistance is 0.61 ohm, and, with that of the conducting wires and galvanometer, 0.66 ohm. Thus proving that the maximum work of a dynamo-electric machine is obtained when the resistance of the

external circuit is equal to the resistance of the electromotor. Again, we notice that as the resistance of the heating coil increases, the electrical energy appearing as heat increases continuously up to the fourth experiment where it attains its maximum. On increasing the resistance still farther, as in the fifth experiment, the resulting heat falls again. Another noticeable fact is that this maximum production of heat does not represent the whole of the energy in the circuit. Calculated from the volt-webers in the fourth experiment, the total energy circulating is 11.94 horse-powers. According to the law of heat-production, since the external and internal resistances are equal in this experiment, one-half the energy of the circuit should appear as heat in the machine and one-half outside of it.[2] Since, too, the resistance of the heating coil makes up nearly the entire resistance in the external circuit, nearly one-half of the energy of the circuit should appear as heat in the calorimeter. But the amount practically realized was only 2.574 horse-powers, or only 21.56 per cent of the total energy of the current. Further, the figures of the above table show that the electromotive force remains practically constant throughout the series, the mean value being not far from 100 volts. Since the current-strength diminishes as the total resistance increases, the total energy of the circuit, which is measured by the product of the current-strength and the electromotive force, varies as the former of these values. Moreover the energy utilized as heat in calorimeter varies with the resistance of the contained coil, increasing as this resistance increases until it equals that of the machine, and then diminishing again. If we represent the total current-energy by EC as above, then, since $E = CR$, we may have $C^2 R$ representing the total heating effect. The heat varies with R then only when C is constant. When the current-strength varies, the heating effect increases and diminishes in a much more rapid ratio, as the figures of the table show.

In the second series of experiments, the resistance of the circuit was so considerable that the machine could be driven by a

[2] In the first and second experiments, in which the resistance of the heating coil was only 0.204 and 0.310 ohm respectively, the time of running had to be limited to two minutes, owing to the heat developed in the machine and in the conducting wires, the machine being on short circuit.

one and a quarter inch belt. The method adopted was the same as before and the following data were obtained:—

No.	*Speed.*	*Resistance.* Coil.	Total.	*Deflection.*	*Temperature.*	*Time.*
1.	560	1.08	1.81	79°	81° — 99°	5
2.	570	1.08	1.81	79°	83° — 102°	5
3.	600	1.84	2.57	69°	78° — 92°	5
4.	600	2.11	2.84	69°	82° — 94°	5
5.	606	3.54	4.27	11°	77° — 78°	5
6.	640	6.84	7.57	4.5°	74° — 74.5°	5

From these figures we may calculate, by the same method as before, the following values:—

No.	*Tangents.*	*Webers.*	*Volts.*	*Volt-Webers.*	*Horse-powers.*	*Heat-Units.*	*Horse-powers.*
1.	5.145	29.33	53.088	1557	2.088	36	0.8424
2.	5.145	29.33	53.088	1557	2.088	38	0.8890
3.	2.605	14.85	37.560	557.8	0.748	28	0.6552
4.	2.605	14.85	42.170	626.3	0.8396	24	0.5616
5.	0.194	1.11	4.730	5.24	0.0703	2	0.0468
6.	0.079	0.448	3.396	1.52	0.00204	1	0.0234

These results simply confirm and extend the conclusions reached by the discussion of the first series. The final relation between the values obtained will appear more clearly if we calculate, for both series, the percentage of work utilized under the conditions of the experiments.

FIRST SERIES OF EXPERIMENTS.

No.	*EC or C²R'*	*Heat-Units.*	*Horse-powers.*	$\frac{P'}{P}$	$\frac{P''}{P}$	$\frac{P''}{P}$	$\frac{R_e}{R_i}$
1.	2418	138.3	3.235	21.86	4.74	21.70	0.374
2.	3667	210.2	4.920	29.81	12.06	40.45	0.529
3.	3664	208.8	4.886	34.88	16.79	45.97	0.691
4.	4053	232.3	5.345	45.52	21.56	47.36	0.971
5.	2703	155.0	3.624	59.67	37.75	63.26	1.622

SECOND SERIES OF EXPERIMENTS.

1.	929	53.24	1.245	59.67	40.36	67.64	1.662
2.	929	53.24	1.245	59.67	42.59	71.38	1.662
3.	465.2	26.67	0.624	64.79	66.89	103.24	3.176
4.	405.7	23.24	0.544	83.42	87.60	105.00	2.779
5.	4.846	0.249	0.0583	82.90	66.57	80.30	5.279
6.	1.376	0.079	0.0018	90.36	———	———	10.131

The second column in these tables represents the volt-webers of energy available in the heating coil, and is equivalent to C^2R'.

Since one volt-weber is equal to .05732 heat unit (pound-degree F.) column third is obtained by multiplying column second by this decimal. And as one horse-power is equal to 746 volt-webers, column fourth is obtained by dividing column second by this number. In the fifth, sixth and seventh columns, P represents the total energy of the circuit, expressed in horse-powers, P' the energy theoretically available in the heating coil, and P'' the energy actually obtained in the calorimeter, expressed in the same unit. Column fifth, therefore, gives the ratio of the theoretical effect to the total effect, expressed in percentages. Hence the values there given represent the theoretical efficiency of a heating coil having the resistance of the one used in each particular experiment. Column sixth gives the percentage of effect actually realized in heating the water. Column seventh gives the ratio in percentages, of these last two values; or in other words the percentage of the energy theoretically available which was actually obtained in the experiment. On examining the figures, we notice that the first ratio continues to increase steadily throughout. This is as it should be, since this column represents essentially the ratio of the resistance of the heating coil to that of the whole circuit, which ratio increases continually. In the second place, the ratio which the actual energy obtained in the calorimeter bears to that of the entire circuit also continues to increase throughout. And finally the seventh column shows us that the percentage of useful effect increases from first to last. As these tables are arranged on the basis of an increasing resistance both partial and total, the general conclusion follows that the percentage of useful effect, both as regards theoretical and actual yield, increases as the resistance of the circuit increases; or better, as the ratio of the resistance of the external to the internal circuit increases. This increase in the ratio of the resistance is shown in column eight.

Since we have shown above that the maximum work obtainable as heat is reached in the fourth experiment of the first series, while now it appears that the percentage of efficiency continues to rise throughout the experiments, it is evident that the absolute efficiency of the machine is a value of quite a different order from the relative efficiency. The maximum amount of heat-energy obtainable in the calorimeter with a given machine, being one thing and the proportion of the current-energy thus utilized being quite another. Further experiments must be made to ascertain

the conditions under which the largest amount of energy can be utilized in the external circuit. To do this, the experiments must be made under exactly the same circumstances, the current-strength must be the same and the total resistance the same while the ratio of the external to the internal resistance must be varied. This may be done, either by using a machine whose internal resistance may be varied, or by adding to the external circuit and increasing its electromotive force to compensate for the increased resistance.

A third series of experiments was made simply with the view of ascertaining how long it would take to boil a gallon (8 pounds) of water by means of a resistance coil. The machine was driven by a two inch belt and the data of the experiment were as follows: —

		RESISTANCE.				
No.	*Speed.*	*Coil.*	*Total.*	*Deflection.*	*Temperature.*	*Time.*
1.	800	2.00	3.00	79°	87° — 132°	5
2.	800	2.00	3.00	79°	132° — 206°	5
3.	800	2.00	3.00	79°	175° — 206°	5
4.	800	2.00	3.00	79°	206° — 212°	1.5

Calculating the various values as before from these data, we have the following results: —

No.	*Tangents.*	*Webers.*	*Volts.*	*Volt-Webers.*	*Horse-powers.*	*Heat-Units.*	*Horse-powers.*
1.	5.145	29.33	87.99	2581	3.461	72	1.684
2.	5.145	29.33	87.99	2581	3.461	68.8	1.609
3.	5.145	29.33	87.99	2581	3.461	49.6	1.161
4.	5.145	29.33	87.99	2581	3.461	32	0.749

It will be noticed that in the first of the above experiments the heat communicated to the water was very nearly half (48.06 per cent) of the total energy in the circuit. But as the temperature of the calorimeter rose, the loss by radiation and convection became continually greater, thus diminishing the efficiency. The fact here shown is that a gallon of water was raised from the temperature of 87° to the boiling point by means of a coil of two ohms resistance, in 16.5 minutes. Eggs were cooked in the water while boiling.

On the question of the cost of heating by electricity, the main point, of course, is the cost of the electricity. One horse-power (or 33,000 foot-pounds of energy per minute) as we have seen, corresponds to 746 volt-webers of current per second, equivalent to

42.7 heat-units per minute. The cost of a horse-power is very variable but for the larger class of steam engines burning coal, a fair average is perhaps four cents per hour. Hence 1,980,000 foot-pounds, or about 2,500 heat-units, costs four cents. Using therefore such a steam engine to drive a dynamo-machine utilizing 87 per cent of the energy applied to it, and allowing one-quarter for the heat-energy realized in actual practice, the cost of 100 heat-units would be about eight-tenths of a cent. If the dynamo-machine be driven by a gas-engine, the cost is somewhat greater. The Otto silent gas engine, perhaps the best of its class, requires, on the average, 21.5 cubic feet of gas per hour to produce one horse-power. At the rate of $2.00 a thousand feet for gas, one horse-power would cost about 4.3 cents, or nearly eight per cent more than when steam is used. Hence the cost of 100 units of heat produced by the dynamo-machine under these conditions would be not far from nine-tenths of a cent. Another and a very promising method of producing electricity cheaply is by means of thermo-batteries, which aim to utilize the heat of the fuel by converting it into electricity directly. The latest thermo-battery which has been constructed is that of M. Clamond which, with a consumption of about 21 pounds of coke per hour, generates a current which in mechanical energy is equivalent to something over two horse-powers. If we allow the coke to cost $4.00 per ton, a horse-power per hour, generated in this way, would cost 2.1 cents, or something more than half the price of the same power produced by steam. If only one-quarter of the current energy be utilized, the cost of 100 heat-units generated by thermo-electricity would be about four-tenths of a cent.

These results will be increased in value if we compare them with the cost of direct heating by either solid or gaseous fuel. The amount of energy in a pound of coal corresponds to about 12,000 units of heat and in a cubic foot of gas to about 650 heat-units. But practically, a pound of coal will not evaporate over nine pounds of water, equivalent to about 8700 heat units. And a cubic foot of gas may be assumed not to yield over 150 heat-units in actual practice. To produce 100 heat-units therefore would require one eighty-seventh of a pound of coal, or two-thirds of a cubic foot of gas. With the coal at $4.00 per ton, 100 units of heat would cost something over two-thousandths of a cent. And with gas at $2.00 per thousand feet, the cost of 100 heat-

units would be thirteen-hundredths of a cent. If we assume the above values to be correct, and no error has been made in the calculation, we see that calling the cost of 100 heat-units produced by the direct burning of coal 1, the cost of heating by gas directly is 65, that of heating by a thermo-electric current is 200, that of electrical heating by steam-power is 400 and that by a gas engine is 450. These results may be tabulated as follows: —

RELATIVE COST OF 100 HEAT-UNITS.

Method.	*Price.*	*Heat-units.*	*Cost of* 100 *heat-units.*	*Ratio.*
A. By combustion.				
a. Of coal	$4 pr ton	1 lb. = 8700	.002	1
b. Of coal gas	$2 pr 1000 ft.	1 cu. ft. = 150	.130	65
B. By electricity.				
a. By dynamo-machines.				
α. Driven by steam 1 H. P. = 4 cents.		1 H. P. = 2500	.100	400
β. Driven by gas engine 1 H. P. = 4.3 cts.		1 H. P = 2500	.900	450
b. By Thermo-battery. Coke $4 pr ton,		1 lb. = 250	.400	200

The experiments above detailed were made in Ansonia, Connecticut, at the factory of Wallace and Sons. To them, therefore, I desire to express my sincere obligations for the facilities given and the assistance rendered. To Mr. Charles Stowell my thanks are especially due for valuable personal services.

PHILADELPHIA, August 20, 1879.

ON A CURIOUS CASE OF CRYSTALLIZATION OF CANADA BALSAM. By GEORGE F. BARKER, of Philadelphia, Pa.

MY object in the present paper is simply to put on record the facts concerning a remarkably perfect negative crystallization of Canada Balsam, and thus to call the attention of observers to the matter, in the hope of accumulating more data not only with reference to this phenomenon but also to those which are allied to it. Some time in the early spring of 1875, a hunting expedition left Rawlins, Wyoming Territory, and went up into the Sweetwater region, a hundred miles or so north of that place, in search of game. During their absence, a field glass belonging to one of the

party was lost. In the summer of 1878, a party of Ute Indians came into Rawlins having the lost field glass in their possession. It had lain out exposed to the weather for over three years, the case showing good evidence of the hard usage it had undergone.

The eye lenses were in apparently perfect condition. But the object glasses were entirely ruined for the purpose for which they were intended, being covered with an abundant arborescent crystallization which rendered them partially opake. My attention was first called to them by Mr. R. M. Galbraith of Rawlins, at that time their owner. He supposed that the crystallization was

in the glass itself, and accordingly sent one of the lenses—an achromatic combination—to me in order that I might have a new pair made exactly like the crystallized ones, to be put in their places. On examination, however, in connection with Mr. Zentmayer of this city, it was at once evident that the crystallization referred to was not in the glass as had been supposed, but only in the balsam with which the glasses of the achromatic had been cemented together. Since therefore, by cleaning off the old and crystallized balsam and re-cementing the lenses, the object glasses would become perfect again and the expense of new lenses be saved, I

wrote to Mr. Galbraith to send me the second and more beautifully crystallized objective in order to re-cement that also. This he accordingly did; but with an expressed regret that the beautiful forms must be sacrificed. On receiving the glass, the crystallizations were so beautiful that I too desired to preserve them in some form. Taking them to Mr. E. L. Wilson of this city he was kind enough to take an interest in the matter and to produce for me an exquisite set of four photographs of the crystals, quite as beautiful as the originals. The less beautiful glass was photographed but once. But the other had three negatives taken of it under three different lights. I have pleasure in presenting to the Section prints from each of the four negatives. (The accompanying wood cut has been engraved from one of the best of these photographs.)[1] After the negatives had been taken, the glasses were cleaned and re-cemented and then were in perfect condition. They were returned to Mr. Galbraith, with a set of the photographs.

On examining critically the photographs it will be observed that the crystallizations are arborescent and of great beauty. The minuteness of the subdivisions is quite remarkable, the more so when we consider the viscous material in which these crystallizations took place, and the manner of their formation. The most curious thing about them however, undoubtedly, is the fact that the forms themselves are hollow, being cavities surrounded by the crystallizing material, the balsam. This fact of itself would seem to negative the two most natural hypotheses of the formation of these crystals. In the first place, it might be supposed that the crystallization is due to the non-homogeneity of the cementing material. Canada balsam, as is well known, is a mixture of two or more resins dissolved in a volatile oil, probably a terpene. Now since one of these resins is crystallizable, the suggestion at once occurs that the intense cold of the winter where the glass was exposed has caused the separation of this resin from the other constituents, in the crystalline form. Or, in the second place, the phenomenon might be attributed to a frost-like or dendritic crystallization of water or of a saline solution, drawn in between the glasses by capillary attraction. Neither of these explanations seems to accord with the fact, since in either, the resulting crystals would be solid and not hollow. When viewed with a magnifying

[1] I am indebted to the courtesy of the *Scientific American* for this electrotype cut.

glass, the branches, especially near their ends, show plainly that the crystallization has progressed gradually by a withdrawal of the material from several nuclei at once, these becoming the centers from which the crystals have radiated. The evidence of this is particularly strong near the ends of the larger branchlets, where can be seen curves concentric with the rounded end of the branch, for some distance inward. The edges of these arborescent forms, moreover, are all rounded, as if in the viscous material only the stronger forces had been able to act. In view of all the facts, the most probable theory is that we have here a crystallization produced, or at least directed, by some constituent of the balsam itself. But the conditions under which the glass must have been exposed in order to cause this result do not seem clear. It is easy to understand that when a substance is passing to the solid state from solution, the molecules may be arranged in the form of regular crystals by their polarity. Nor is it difficult to comprehend the reverse process and to see how crystalline structure may be developed in an irregular mass by the action of a solvent which takes apart the molecules according to the law of their constitution. But it is not easy to understand how the contraction of the balsam, produced by the slow removal of some volatile constituent, perhaps, should cause the gradual withdrawal of the material from certain well defined centers so as to produce these beautiful forms of arborescent crystallization. As will be easily seen on inspection, the branchings do not take place at right angles, but at angles of about thirty degrees, which suggests of course, that the forms are hexagonal.

[NOTE.—Since preparing the above paper, I have received from Mr. Galbraith another letter in which he informs me that about the last of July, 1879, the Ute Indians brought into Rawlins a second pair of field glasses, which they said they had found in the White River country. These glasses had the United States Signal Service mark upon them, and had the appearance of having been exposed to the weather for a long time, the lacquer being all off the case and the brass corroded. Curiously enough, there was the same arborescent crystallization in the balsam between the components of the object glass which was observed in the former case; only, as Mr. Galbraith writes, they were much more beautiful than those which he sent me.]

On the Phenomena of heating Metals in vacuo by means of an Electric Current. By Thos. A. Edison, of Menlo Park, N. J.

In course of my experiments on electric lighting I have developed some striking phenomena arising from the heating of metals by flames and by the electric current, especially wires of platinum and platinum alloyed with iridium. The experiments are still in progress.

The first fact observed was, that platinum lost weight when heated in a flame of hydrogen, that the metal colored the flame green, and that these two results continued until the whole of the platinum in contact with the flame had disappeared.

A platinum wire four thousandths of an inch in diameter and weighing 306 milligrammes was bunched together and suspended in a hydrogen flame. It lost weight at a fraction less than one milligramme per hour as long as it was suspended in the flame.

When the platinum wire is stretched between two clamping posts and arranged to pass through a hydrogen flame, it is colored a light green, but when the temperature of the wire is raised above that of the flame by passing a current through it, the flame is colored a deep green. To ascertain the diminution in the weight of a platinum wire when heated by the electric current, I placed between two clamping posts a wire five thousandths of an inch in diameter and weighing 266 milligrammes. This wire, after it was brought to incandescence for twenty minutes by the current, gave a loss of three milligrammes. Afterwards it was kept incandescent for one hour and ten minutes, at which time it weighed 258 milligrammes, a total loss of 8 milligrammes. Another wire, weighing 343 milligrammes was kept moderately incandescent for nine consecutive hours, after which it weighed 301 milligrammes, showing a total loss of 42 milligrammes. A platinum wire twenty one-thousandths of an inch in diameter was wound in the shape of a spiral, one-eighth of an inch in diameter and one-half an inch in length. The two ends of the spiral were secured to clamping posts, and the whole apparatus was covered with a glass shade 2½ inches in diameter and 3 inches high. Upon bringing the spiral to incandescence for twenty minutes, that part of the globe in line with the sides of the spiral became slightly darkened; in five hours the deposit became so thick that the incandescent spiral

could scarcely be seen through the deposit. This film, which was most perfect, consisted of platinum and I have no doubt but large plates of glass might be coated economically by placing them on each side of a large sheet of platinum kept incandescent by the electric current.

This loss in weight, together with the deposit upon the glass, presented a very serious obstacle to the use of metallic wires for giving light by incandescence, but this was easily surmounted after the cause was ascertained. I coated the wire forming the spiral with the oxide of magnesium, by dusting upon it finely powdered acetate of magnesium. While incandescent the salt was decomposed by the heat and there remained a strongly adherent coating of the oxide. This spiral, so coated, was covered with a glass shade and brought to incandescence for several minutes, but, instead of a deposit of platinum upon the glass, there was a deposit of oxide of magnesia. From this and other experiments I have become convinced that this effect was due to the washing action of the air upon the spiral. That the loss of weight in and the coloration of the hydrogen flame was also due to the wearing away of the surface of the platina by the attrition produced by the impact of the stream of gases upon the highly incandescent surface, and not to volatilization as commonly understood. After the experiment last described, I placed a spiral of platinum in the receiver of a common air pump and arranged it in such a manner that the current could pass through while the receiver was exhausted. At a pressure of 2 millimeters, the spiral was kept at incandescence for two hours before the deposit was sufficient to become visible. In another experiment, at a higher exhaustion, it required five hours before a deposit became visible.

In a sealed glass bulb, exhausted by a Sprengil pump to a point where a $\frac{1}{4}$ inch spark from an induction coil would not pass between points one millimeter apart, was placed a spiral, the connecting wires passing through the glass. This spiral has been kept at the most dazzling incandescence for hours without the slightest deposit becoming visible.

I will now describe other and far more important phenomena connected with my experiments.

If a short length of platinum wire, one thousandth of an inch in diameter, be held in the flame of a Bunsen burner, at some part

it will fuse and a piece of the wire will be bent at an angle by the action of the globule of platinum. In some cases there are several globules formed simultaneously, and the wire assumes a zigzag shape.

With a wire four one-thousandths of an inch in diameter this effect does not take place, as the temperature cannot be raised to equal that of the smaller wire, owing to the increased radiating surface and mass. After heating, if the wire be examined under a microscope, that part of the surface which has been incandescent will be found covered with innumerable cracks. If the wire be placed between clamping posts and heated to an incandescence for twenty minutes, by the passage of the electric current, the cracks will be so enlarged as to be seen with the naked eye. The wire under the microscope presents a shrunken appearance and is full of deep cracks. If the current is continued for several hours these effects will so increase that the wire will fall to pieces.

This disintegration in platina, long subjected to the action of a flame, has been noticed by Prof. John W. Draper. The failure of the process of lighting invented by the French chemist, Tessie du Motay, who raised sheets of platinum to incandescence by introducing it into a hydrogen flame, was due to the rapid disintegration of the metal.

I have ascertained the cause of this phenomenon and have succeeded in eliminating that which produces it, and in doing so have produced a metal in a state hitherto unknown and which is absolutely stable at a temperature where nearly all substances melt or are consumed; a metal which, although originally soft and pliable, becomes as homogeneous as glass and as rigid as steel. When wound in the form of a spiral, it is as springy and elastic when at the most dazzling incandescence as when cold, and which cannot be annealed by any process now commonly known.

The cause of this springing and cracking of the wire is due entirely to the expansion of the air in the mechanical and physical pores of platinum, and the contraction upon the escape of the air.

Platinum, as sold in commerce, may be compared to sandstone, in which the whole is made up of a great number of particles with many air spaces. The sandstone upon melting becomes homogeneous and no air spaces exist. With platinum or any

metal, the air spaces may be eliminated and the metal made homogeneous by a very simple process. This process I will now describe.

I had made a large number of platinum Iridium spirals, all of the same size and from the same quality of wire. Each spiral presented to the air a radiating surface of three-sixteenths of an inch, five of these were brought by the electric current up to the melting point. The light was measured by a photometer, and the average light was equal to four standard candles for each spiral just at the melting point. One of the same kind of spirals was placed in the receiver of an air pump, and the air exhausted to two millimeters, a weak current was then passed through the wire to slightly warm it, for the purpose of assisting the passage of air from the pores of the metal into the vacuum. The temperature of the wire was gradually augmented, at intervals of ten minutes, until it became red. The object of slowly increasing the temperature was to allow the air to pass out gradually, and not explosively. Afterwards, the current was increased at intervals of fifteen minutes. Before each increase in the current the wire was allowed to cool, and the contraction and expansion at these high temperatures caused the wire to melt together at the points previously containing air. In one hour and forty minutes this spiral had reached such a temperature without melting that it was giving a light of twenty-five standard candles, whereas it would undoubtedly have melted before it gave a light of five candles had it not been put through the above process. Several more spirals were afterwards tried with the same result. One spiral, which had been brought to these high temperatures more slowly, gave a light equal to thirty standard candles. In the open air this spiral gave nearly the same light, although it required more current to keep it at the same temperature.

Upon examination of these spirals which had passed through the vacuum process, by the aid of a microscope, no cracks were visible, the wire had become as white as silver and had a polish which could not be given it by any other means. The wire had a less diameter than before treatment, and it was exceedingly difficult to melt in the oxyhydrogen flame as compared with untreated platinum, it was as hard as the steel wire used in pianos and it could not be annealed at any temperature; it was also scarcely attacked by boiling aqua regia.

My experiments with many metals treated by this process has proved to my satisfaction, and I have no hesitation in stating that what is known as annealing of metals, to make them soft and pliable, is nothing more than the cracking of the metal. In every case where a hard drawn wire had been annealed, a powerful microscope revealed myriads of cracks in the metal.

Since the experiments of which I have just spoken, I have by the aid of Sprengel mercury pumps produced higher exhaustions and have, by consuming five hours in excluding air from the wire and intermitting the current, a great number of times succeeded in obtaining a light of eight standard candles from a spiral of wire with a total radiating surface of one-thirty-second of an inch, or a surface about equal to a grain of buckwheat. With spirals of this small size which have not passed through the process the average amount of light given out before melting is less than one standard candle. Thus I am enabled by the increased capacity of platinum to withstand high temperatures to employ small radiating surfaces and thus reduce the energy required per candle light. I can now obtain eight separate jets, each giving out an abundantly steady light, and each equal to sixteen standard candles or a total of one hundred and twenty-eight standard candles by the expenditure of 30,000 foot pounds of energy, or less than one horse power.

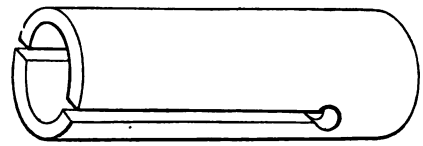
As a matter of curiosity I have made spirals of other metals, and excluded the air from them in the manner stated. Common iron wire may be made to give a light greater than platinum not treated. The iron becomes as hard as steel and just as elastic. Nickel is far more refractory than iron. Steel wire used in pianos becomes decarbonized, but remains hard and assumes the color of silver. Aluminum melts only at a white heat.

In conclusion, it may be interesting to state that the melting points of many oxides are dependent upon the manner of applying heat. For instance, pure oxide of Zirconium does not fuse in the flame of the oxyhydrogen blowpipe, while it melts like wax and conducts electricity when on an incandescent platinum spiral which is at a far lower temperature. On the other hand oxide of aluminum easily melts in the oxyhydrogen flame, while it only vitrifies on the platinum spiral.

ON A RESONANT TUNING FORK. By THOMAS A. EDISON, of Menlo Park, N. J.

[ABSTRACT.]

FOR the purpose of rendering audible the sounds produced by tuning forks, they are generally mounted upon resonant boxes containing a column of air whose vibrating period is the same as that of the fork. I have devised a modification of this plan, by



which the box is dispensed with, the resonant chamber, as is shown in the cut, being formed by the prongs themselves. To make the fork, a thick tube of bell-metal, one end of which is closed, has a slit sawed longitudinally through its center, the slit being nearly to the closed end. This slit divides the tube equally and gives two vibrating prongs, analogous to those of a fork. To bring the prongs into unison with the column of air between them, the tube is put in a lathe and turned thinner until the desired point is reached and the two are in unison. Thereupon the sound of the fork is powerfully reinforced.

METHODS FOR TESTING FARADIC MACHINES. By FRANCIS R. UPTON, of Menlo Park, N. J.

WHEN experimenting with machines for generating large quantities of electricity the need of a general term to apply to them is strongly felt. The same instrument may be made either a dynamo-electrical machine or a magneto-electrical machine by a simple change in the connections, in no essential altering the method of procuring the current. Mr. Edison last winter proposed that they be called Faradic in honor of Faraday. Thus

naming the machines may be taken as a monument to the investigator who found the first traces of the phenomena involved, and gave the clearest explanation of the facts and laws involved. More than this it may be considered as a monument proposed to the memory of the greatest experimental investigator of the laws of electricity, by one who has been so successful in applying them. If the term is adopted it will be an enduring monument, for there is every prospect that many thousands of these machines will come into use in a few years for lighting purposes and for the transmission of power.

In testing such machines it is of the highest importance to know the amount of power absorbed, for they have only one function, the transformation of energy, so that for accurate measurements a good transmitting dynamometer is necessary. Before a form was adopted the faults of the existing styles were thoroughly discussed.

When a spring is used to transmit power, there is always some play in the bearings of the apparatus used to translate the motion of the spring to an index. The constant of the spring is also liable to change from strain. As this constant also is determined when the machine is at rest, it is extremely difficult to feel sure that when in rotation centrifugal force will not disturb some of the parts, thus altering it. The small amount of deflection that can be readily obtained from a spring tends to render all readings uncertain.

In one form of dynamometer designed by Mr. Edison magnets were used attached to the driving wheel to drag after them armatures attached to the receiving wheel. The number of pounds it took to detach the armatures was found with the various strengths of current while the machine was at rest and the results tabulated. It was hoped that when in motion the table thus proposed could be utilized, but it was found that the jar of the belt detached the armatures long before a correct measurement could be obtained.

In the Batchelor form of dynamometer, Diglers Poly. Journal, 1844, Vol. 2, the power is transmitted by means of gears; the teeth of the wheels are used as the points of the system of levers by which the power is measured and since these can never be made perfectly exact and must necessarily wear, there is a large element of uncertainty introduced. Prof. Trowbridge mentions in his Newport tests that it could not be used for very large or small amounts of power.

The Von Hefner Alterneck dynamometer has this fault, that only a small movement in the belt is utilized, and in a manner that the slapping motion has a maximum of effect. In all the forms mentioned a small weight is used which is measured either by a poor spring balance or by a scale with uncertain and changing bearings, or indicated by the amount of pull in a transverse direction of a stretched belt. Indeed no form would be chosen for a weighing machine, though the mechanism of a dynamometer is nothing more than this.

Since the speed can be measured to any degree of accuracy, to make an accurate instrument it is only necessary to use a good weighing apparatus, and this I think Mr. Edison has done. The principle on which his instrument rests is the same as that of the Von Hefner Alterneck; the speed of a belt and the strains on it are measured, from which is calculated the foot pounds carried by it.

The driving side of the belt is carried under the pulley attached to a weight, from which is placed so far below the line of the driving and driven pulley, that nearly double the strain on the belt is lifted, as in the case of an ordinary block. To weigh this amount, the weight is placed on a platform scale and the diminution due to the pull from the belt measured. A large load of 900 pounds was used so that the jar due to the movements of the belt is so distributed as to produce very little effect on the scale.

The belt ran about 1000 feet in a minute so that 100 pounds difference represented about a horse and a half power. Since the scale showed half a pound, the results were easily measured within one per cent., making the maximum which could be transmitted 13.5 H. P., though the same weight could be made to answer for transmitting larger amounts of power by increasing the speed.

The volt was found by assuming the E. M. F. of a Daniells cell as 1.08 volts. The absolute value of the Daniells is of little consequence so long as a certain value can be assumed by common consent, so that various determinations may be compared with each other, until new determinations have been made of the absolute value. The form of cell described by Wiedermann, V. II, Section 1057 was used consisting of electro-deposited [illegible] in a concentrated solution of copper sulphate sepa[illegible] porous cup from a concentrated solution of so[illegible] containing a plate of amalgamated zinc.

If in any circuit the difference of potential between the two ends of a resistance be known the current may readily be calculated. The method of measuring this difference was as follows.

A deflection from ten standard Daniells cells of this standard battery was obtained on a high resistance galvanometer, through 60,000 ohms. By properly adjusting the galvanometer a deflection of 108 scale division was obtained or ten for every volt's difference of potential between extremities of the 60,000 ohms.

If, for example, one hundred scale divisions were obtained by shunting the 60,000 ohms with an ohm in the main circuit, it would show that the ten volts were active on this or a current of ten vebers were circulating.

In calculating the energy in the circuit 44.3 foot pounds were taken as the amount given off from an ohm when a veber is circulating through it. Thus in the illustration mentioned we should have $10^2 \times 44.3 = 4430$ foot pounds given off by ten vebers on one ohm. By multiplying this amount by the number of ohms in the circuit, the total energy of the electricity may be calculated. The resistances were measured by comparison with a standard set made by Elliot Bros. of London. Those used consisted of copper wire wound in the open air around supports. A very convenient form consisted of a framework one foot three inches in height, and six inches across, wound with No. 22 wire eight turns to an inch, each box having a little more than three ohms in it. By placing these in multiple arc the heating effect of the current could be reduced to a very small amount. As a precaution the apparatus was so arranged that the resistance could be measured immediately after the strong current ceased. In connection with this method Trowbridge's form of electro-dynamometer was used. This instrument is most admirably adapted for practical use, as the parts are so heavy as not to be easily affected by jars, and above all the presence of iron has very little effect on it. I have used it placed on an ordinary table in the machine shop near the magnets, and found its indications extremely reliable. It was used by the method of sines since by so doing the error due to the attraction of the earth's magnetism could be eliminated.

The first machine tested was the medium sized Gramme and the following relations were established. A constant field was made by passing the current from another machine around the magnet, and measurements were made of the currents produced

by the armature revolving in this field when the resistance in the circuit was varied. The number of volts was calculated from this.

The results are shown in table I, the column marked vebers denoting the current while that marked volts indicates the electro-motive force.

TABLE I.

VEBERS.	VOLTS.
4.72	47.7
6.4	47.
7.0	43.2
8.9	35.6
9.9	35.1
10.8	33.1
12.0	30.2

It will be noticed that the E. M. F. of the machine decreases as the current taken from it increases. This is analogous to the case of a battery which becomes polarized as the strength of the currents taken from it are increased. This fall in electro-motive force may be called the polarization of the armature and is due to the saturation of the ring of iron wire which forms it.

In another series of tests, the strength of the current through the wire which surrounds the magnets was varied, while the armature was run at a fixed speed. The resistance in the armature circuit was kept constant and the electro-motive force calculated.

The column marked vebers (see table on p. 183) shows the number of vebers on the magnet and that marked volts the E. M. F. of the armature.

If the curve be constructed using the axis of X for the number of vebers and of Y for the volts it will be found that the volts do not increase proportionally with the strength of the currents around the magnets. This is due to the saturation of the magnets making the field.

If a Faradic machine have the magnets put in the same circuit with the armature a curve would be obtained similar to that given

for the Siemen's machine in a paper read by Dr. Hopkinson before the Institute of Mechanical Engineers in London, April 25, 1879. In this it will be found that as the exterior resistance is decreased a point is reached where the E. M. F. of the machine increases very rapidly and after that slowly. This curve is really a combination of the curves from the two tables given taking in consideration the mutual interaction of the two sets of wires.

TABLE II.

VEBERS.	VOLTS.
2.86	23 3
3.8	27.2
8.9	30.2
4.	31.5
4.7	36.1
8.1	50.
8.4	55.

I have tested the Gramme also for the effect of change in speed when the field was constant and found that the rise in E. M. F. was nearly proportional to the increase of speed.

In all the tests given the spark on the commutator was so small that no allowance was made for the additional resistance which it introduced.

No tests are given of Mr. Edison's machines since he does not wish to put on record what he knows are experimental results, for he feels sure that he can better nearly all that he now has. No tests of the power absorbed by the Gramme are given since a good transmitting dynamometer was not at my disposal at the time that a Gramme machine was in Mr. Edison's possession.

One result which a machine of Mr. Edison's has shown may be mentioned. At 700 revolutions in a minute with one-sixth of a horse power consumed on the magnet he has obtained 130 volts from an armature having a resistance of .65 ohm.[1]

[1]At time of going to press, he has a machine with .14 ohm on the armature, which at 1000 revolutions gives 110 volts, and converts 85 to 90 per cent. of the power given to it by the belt into electricity.

A Faradic machine is to me only a means of throwing an E. M. F. on a line so that the test of the value of a machine is in the number of the volts it can bring into action per unit of resistance contained in it, the amount consumed in driving the machine and supplying the magnets being considered. The best economy in magnets properly constructed is when the interest on their cost equals the cost of the horse power lost in the shape of heat in the wire around them. All that the current does when the magnet is once magnetized is to put a peg in to hold the magnetization to its maximum, having no active effect beyond heating the wire.

Before the next meeting of the Association I propose to make a series of measurements of Faradic machines which I hope then to present. Many variations will be made in the proportions of the magnets and the armatures of Mr. Edison's form of machine to find the laws on which the generating of currents is founded so as to be able to predict the result of changes in dimensions. The series spoken of will then show the relation between the size of the magnets, the size and amount of iron in armature and the E. M. F. of the machine.

On the First Results from a New Diffraction Ruling Engine.

By William A. Rogers, of Cambridge, Mass.

The best diffraction gratings are subject to three classes of errors: —

First:—The accidental errors of single subdivisions, which are for the most part due to the irregular action of the ruling diamond upon a non-homogeneous metal.

Second:—The periodic or systematic errors which are a function of one revolution of the ruling screw.

Third:—Errors which depend upon the position of the nut upon the screw, and which are equivalent to a varying pitch of the screw. The errors of this class may be due either to the form of the screw itself, to a variation in its diameter, or to an imperfect mounting of the screw. The pitch of even a perfect screw practi-

cally undergoes a slight change with every variation of the amount of the friction between the moving parts of the ruling engine.

Let us take, as a type, the magnificent rulings of Mr. L. M. Rutherford executed by Mr. D. C. Chapman. These gratings easily surpass all others in their resolution of the lines of the solar spectrum. Here the first class of errors is so far wanting that it is safe to say of a given space that it is so nearly equal to its neighbor that the most rigid investigation with the microscope will fail to reveal any difference.

For separate, narrow and adjacent spaces then, a well-made and well-mounted screw is subject to less liability to error than the microscopic observation with which the comparison is made, even under the manipulation of the most skilful observer.

With regard to the second class of errors, viz. :—those which are a function of one revolution of the ruling screw, it is to be said that the danger of their occurrence is far greater. Indeed I am not aware that they have ever been entirely overcome. In the measures of single narrow spaces they easily escape detection. For example, suppose we have a screw having a pitch of one-twentieth of an inch, in which the first half of one revolution differs from the second half by one ten-thousandth of an inch. Each half will then have an error of one twenty-thousandth of an inch. But this maximum value is made up of successive increments of very minute errors, starting with the zero of revolution. If the graduations are ten thousand to the inch, there will be five hundred spaces in half a revolution of the screw. This maximum value then of one twenty-thousandth of an inch, a quantity easily measurable, will be made up of five hundred additions of the errors of the successive individual spaces. If the error is a constant one for each space, its value will therefore be only one ten-millionth of an inch, a quantity far beyond the ultimate limit of measurement with the microscope. When by one hundred successive additions the error amounts to one hundred-thousandth of an inch, it will then be barely within the limits of detection.

In Mr. Rutherford's screw the errors of this class are partly overcome by giving an eccentricity to the index of the screw sufficient to neutralize them at the quadrant points of revolution; that they are not entirely eliminated is shown not only by the actual measurement of distant lines, especially at the octant points of revolution, but also by the fact that the surface-waves resulting

from the residual systematic errors are easily seen with the unaided eye when the gratings are examined with a monochromatic flame.

In the investigations of the wave-lengths of light hitherto made, no attention has been paid to the periodic errors which are a function of one revolution of the ruling-screw. Our present knowledge of wave-lengths depends on the supposition that the gratings from which they were determined are homogeneous throughout their whole extent. If I am not mistaken, both Angström and Van der Willigen, who have done the best work in this direction, obtained the value of one interval by dividing the distance between the end lines by the number of spaces. It is at least possible that the error introduced through the neglect to take into account the varying pitch of the screw may be of appreciable magnitude. I can now only note in this connection that when oil or grease is used as a lubricant, the curve which represents the periodic errors usually has a perceptibly different form for each revolution. The compound error thus developed introduces a class of secondary systematic errors analogous to those described in the third class.

After a somewhat careful study of these three classes of errors in connection with the ruling engine constructed for me by Buff & Berger of Boston, I determined about two years ago to attempt the hazardous and costly experiment of constructing a new machine which should be capable of producing a grating homogeneous throughout its whole extent. In the execution of this work I was more than fortunate in securing the coöperation of Mr. Chas. V. Woerd, the mechanical superintendent of the Waltham Watch Factory. My warmest thanks are also due to the Manager and Treasurer of the Company, Mr. R. E. Robbins, for consenting to undertake a task somewhat outside of the regular work of the Factory. To Mr. Woerd I committed the entire arrangement of the details of the new machine, after deciding upon the general principles of its construction.

The new machine is now so nearly completed that some provisional work has already been done with it. It would be premature to say that it will rule a grating absolutely without measurable errors. The resolution of solar lines must be the final test, and the decision on this point I must leave to those who may use the gratings which I hope soon to make.

I venture the assertion, however, that it is the most perfect piece of work ever done in this country, and I doubt if its superior is to

be found abroad. I feel the more free to say this because the credit for the execution belongs entirely to Mr. Woerd and to Mr. George F. Ballou who has done nearly all of the work.

This is not the place for a detailed description of the machine. I will only state the general principles on which it is constructed.

(*a*). In the usual construction of a precision-screw, it is the custom to grind and polish the threads with fine emery by means of a lead nut, after the thread has been cut as perfectly as possible in the lathe. A definite relation then exists between the threads and the centers on which they are cut. Now in grinding and polishing, the lead nut is usually held by the hand as it traverses forwards and backwards, and the test of the uniformity of the threads is entirely one of feeling. But during this operation *the relation between the threads and the centers may be entirely changed*, since the action of the lead nut no longer bears any fixed relation to the centers. Hence when the screw is mounted with respect to its centers we may always expect systematic errors of various kinds.

In the construction of the screw of the Waltham machine an attempt has been made to avoid the errors introduced in this way. The bottom of the thread was, at the suggestion of Mr. Woerd, entirely cut away, giving freedom in the action of the emery upon the faces of the threads. The screw rests in semicircular bearings, and is kept in position by its own weight. The conical ends are made of tempered steel. One end presses against a polished diamond face ground exactly perpendicular to the axis of the screw. It is kept in contact by means of a steel spring bolt working against the other end. The nut is made a part of the moving bed-plate, and rests directly upon the screw.

(*b*). Usually the aliquot part of a revolution of the screw is secured by means of a pawl acting upon the teeth cut on the index. In this case one is limited to certain fixed arcs of revolution. In the Waltham machine a magnet-arm 24 inches long rests upon the axis of the screw. The end of the arm works between two movable stops. A magnet, fitted to the curvature of the index is attached to the other end. Another magnet is attached permanently to the bed of the machine beneath the index. During the upward movement of the magnet-arm, the first magnet becomes firmly attached to the index carrying it forward an arc of revolution depending on the distance between the stops. During the downward movement of the arm the index is held in position by the second magnet.

It will be seen that the arc of revolution may be made to vary at will between zero and a value limited by the greatest distance between the stops, which in this case corresponds to a motion of a little over one-thousandth of an inch in the screw-plate. The index of the screw regulating the distance between the stops reads directly to about one-millionth of an inch expressed in the corresponding motion upon the ruling screw. Since these divisions can be estimated to tenths, as small a movement as one ten-millionth of an inch can be given to the screw-plate with entire certainty *as far as the mechanical indications of this degree of precision are concerned.*

(*c*). In order to provide for the neutralization of whatever errors might be found to exist in the screw in actual use, the following devices were adopted: —

(1). Instead of allowing the magnet-arm to fall upon a fixed stop, it falls upon a circular templet, having a motion in revolution simultaneous with the index of the screw. A curvature is given to the periphery of this templet which exactly corresponds to those measured errors of the screw which depend on one revolution.

(2). A straight templet runs parallel with the screw to which is given a curvature corresponding to those errors which depend upon the position of the nut upon the screw.

The present indications are that neither of these supplemental corrections will be found necessary.

(*d*). In the investigation of wave-lengths from a given ruled grating there are certain requirements which seem to need experimental as well as theoretical research.

First: It is important to ascertain the best relation between the width of the lines and the width of the intervening spaces. In this machine after having obtained a good line of a given width, the width of the spaces can be varied at will.

Second: All we can say of the wave-length equation $\lambda = \epsilon \sin \theta$ is that it expresses the length of a single wave of light of a given color. When we take into consideration the conditions under which the waves reach the eye, it is at least an open question whether the form of the equation is not somewhat more complex. As an illustration: the law of refraction in passing from one thin stratum of atmosphere to its adjacent one, is quite simple, but it does not follow that this law holds good for the combined strata which make up the atmosphere at a given altitude above the horizon.

In order to ascertain the effect of errors of any class upon the position of the solar lines, it seems important to determine the effect of these errors experimentally. Hence the machine has been constructed in such a way that it is possible to introduce at any point, either any single error of a given magnitude or any combination of errors without interfering with the remaining graduations.

The tremors communicated to the machine by the running machinery of the factory prevent the best work, but the experiments already made justify the hope that when it is permanently mounted upon the firm foundation already prepared for it, work may be done which shall contribute something to our present knowledge of wave-lengths. In this connection also, especial attention will be paid to the expression of all measured distances in terms of the standard Metre of the Archives at a temperature convenient for use. With this view a standard decimetre subdivided into 10,000 equal parts will be taken as the unit of comparison.

As a type of the character of the work already done, I will close this article with a description of two glass plates ruled on different days with the same setting of the stops of the magnet-arm. The stops were set to correspond to a motion of one thousandth of an inch upon the screw. The machine was started at 10 o'clock in the morning. Between 12 and 1 o'clock it remained at rest. It was also at rest during the night. Starting again at 7 o'clock the next morning it was stopped at 9 h., 50 m., having ruled 4001 lines, covering a space of four inches.

The plate was then removed and another one was placed in position. The machine was again started, and this second plate was ruled under nearly the same conditions with regard to time and temperature as the first one.

Having filled the lines with graphite in order to obtain a sharper definition of the edges, these two plates were then placed face to face in a mounting of stiff balsam in the same direction as that in which they were ruled. When the lines at one end were made coincident, not only were the other end lines coincident, but every one of the 4001 lines exactly overlapped its fellow. With a power of 300 I was unable to detect a single case of deviation from exact superposition.

This experiment merely showed that the machine would rule two plates exactly alike under the same conditions, but it gave no

indications with reference to the homogeneous character of the graduations. But when the plates were placed face to face in a direction *opposite* to that in which one of them was ruled, then, coincidence being made between the lines at one end, a test of the homogeneity was found in the coincidence of the remaining graduations.

This coincidence seemed to be perfect for about two inches. At that point there was an abrupt separation amounting to about one eight-thousandth of an inch. This deviation remained a constant for about one inch when it began gradually to diminish and finally disappeared at about one inch and one-half from the point where it first appeared.

This error is probably due to a change of temperature during the nights on which the machine remained at rest. It is rather curious however that the error should have taken this particular form. It is not surprising that it escaped detection when the plates were arranged as first described. In the second case the lines were barely separated, but the separation was sufficient to enable one to measure from center to center. In the first instance, the overlapping of the edges was not sufficient to attract attention.

Harvard College Observatory, Oct. 28, 1879.

An Experimental Solution of a Problem in the Doctrine of Chances. By T. C. Mendenhall, of Tokio, Japan.

Many experimental verifications of the Theory of Probabilities have been made from time to time. Perhaps one of the most remarkable results reached in the investigation of that theory occurs in the solution of a problem doubtless first proposed by Buffon and solved by him, and afterward by La Place (see Todhunter's History of the Theory of Probabilities, article 650). In it is shown the possibility of ascertaining the ratio of the circumference to the diameter of a circle, — by the method of "pitch and toss."

De Morgan, in his Budget of Paradoxes, states that Mr.

Ambrose Smith of Aberdeen made 3,204 trials at this in 1855, with a result of great accuracy and also refers to 600 trials having been made by one of his pupils. De Morgan adds that "this method will hardly be believed until it has been repeated so often that there could never have been any doubt about it."

Having interested my assistants in the laboratory, recently, in questions of this nature, it was determined to repeat the experiment and carry it to a degree hitherto not reached. For this purpose a flat, smooth surface was prepared, about 60^{cm} by 75^{cm} upon which was ruled one set of fine parallel lines at a distance of 3^{cm} from each other. A straight bamboo stick less than 1^{mm} in diameter was cut to a length of 3^{cm} as nearly as possible. This stick was tossed from a conical glass cup about 8^{cm} deep. The ruled surface was placed upon a table somewhat higher than usual and levelled. The whole was arranged in a convenient place in the laboratory so that it need not be disturbed, the object being to accumulate a large number of trials by spending a few leisure moments each day in "tossing" and thus avoid both fatigue and what might be called a "waste of time." A trial consists simply in standing on one side of and near the ruled plane, and "tossing" the stick up into the air from the glass cup which is held in the hand. The stick falls on the ruled surface, and a record is made in a book at hand, of the fact that it does or does not cross one of the parallel lines. At the present writing a total of 12,000 trials has been reached, three persons having "tossed" at different times. According to the doctrine of probabilities the chance that the stick will intersect one of the parallel lines is expressed by the fraction $\frac{1}{2}$.

In the "long run" therefore this fraction ought to express approximately the ratio of the number of intersections to the whole number of trials.

The result of 12,000 trials is as follows:—

Actual	number of intersections . .	7635
Calculated	" " " . .	7639

being a difference between Theory and Experiment of about $\frac{1}{19}$ of one per cent. Not counted in the above 12,000 were 6 trials in which it seemed impossible to decide whether it was a "cross" or a "clear."

Counting these as intersections we have in a total of 12,006.

Actual	intersections	7641
Calculated	"	7643

the error being but little greater that $\frac{1}{4\frac{1}{0}}$ of one per cent.

From the set of 12,000 trials we obtain $\pi = 3{\cdot}143$, and from that of 12,006 $\pi = 3{\cdot}142$.

The value of π was computed at various stages of the experiment — after giving much closer approximations than the above — as indeed it is *possible* from a comparatively small number of trials to obtain a very close approximation. But at 10,000 or 12,000 it seems that the result will not be greatly influenced by the "runs" which are continually occurring. *In the long run* the ratio of intersections to "tosses" must constantly approach a certain result. The number of trials will be largely increased with a view of ascertaining, within certain limits, what is meant by *the long run*. The results of the different "tossers" have been kept separate from each other, and a comparison of them will be made.

ON THE STRENGTH OF AMERICAN TIMBER. By ROBERT H. THURSTON, of Hoboken, N. J.

[ABSTRACT.]

INTRODUCTORY.—One of the earliest investigations planned by the writer when organizing the Mechanical Laboratory of the Stevens Institute of Technology was that here described. Nearly all our knowledge of the strength of timber was derived from foreign sources and was of limited extent, and authorities were somewhat conflicting in statement.[1] It was evident that more work in that department of research was required, and that experiments on the strength of American woods were demanded by engineers and architects in the United States and by members

[1] Compare Barlow and Tredgold with Laslett. Barlow on the Strength and Stress of Timber, London, 1826; Tredgold's Elementary Principles of Carpentry, London, 1870. Laslett on Timber and Timber Trees, London, 1875.

of the profession in Europe, where some American timber — especially our soft pines — is used.

It seemed eminently desirable that the woods examined and experimented upon should be of the kinds used most generally in construction; that the specimens should be of sound, good stock, and that the test-pieces should be carefully and accurately made to standard size and shape. As the best means of securing these desiderata, the Secretary of the Navy and the Chiefs of Bureau were requested to furnish test-pieces of the form and size standard in the Mechanical Laboratory of the Stevens Institute of Technology. The favor was cheerfully granted, and the Naval Constructor, on receipt of orders from the Navy Department, prepared the required specimens at the Brooklyn Navy Yard, at the earliest practicable date, taking a personal interest in securing the desired quality of material and accuracy of workmanship. The samples thus furnished may be regarded as good representations of those American woods which are here treated of.

The samples furnished were of white and yellow (Georgia) pine, locust, black walnut, white ash, white oak and of live oak.

White pine (*Pinus strobus*) is a native of North America, and takes its name from the color of its wood. It grows in all kinds of soil. The best timber is found in cool, damp situations, in the forests of the Northern United States and Canada, between the forty-third and forty-seventh parallels of north latitude. It really flourishes well as far south as Virginia. It grows to great size, reaching a height of upwards of 200 feet, with a diameter of 10. feet at the height of a man's shoulder from the ground. It is the tallest tree in our forests. It sometimes reaches the age of 350 years. Single logs have been cut 36 inches square and 60 feet long.

Its wood is yellowish-white in color, light in weight, rather soft, free from knots, straight grained, and is very easily cut. It is durable only in dry air. It contains very little resin; its leaves are very slender; its cones are very nearly cylindrical and four or five inches long. Its leaves are pale green in color. Its specific gravity is about 0·7 green and 0·5 seasoned. It is used for light carpenters' and joiners' work, and is remarkably well adapted to pattern makers' use. It has been employed to a considerable extent in building wooden bridges. It is not a very strong wood, and swells or shrinks seriously when the hygrometric state of the

atmosphere changes considerably. For many purposes its softness is a serious objection.

The Southern Yellow Pine, "*Long-leaved Pine*" (*Pinus Australis*, *Pinus palustris*), is distributed along the Atlantic coast from Maryland southward, on sandy, light soil. It is probably the most generally useful of our woods, and immense quantities are brought into market.

Its name is sometimes confused with that of the *pitch pine*, and both kinds of wood are known in the Eastern States as *hard pine*.

Both kinds are extensively used by Atlantic ship builders for planking, beams, etc., but seldom for any part of the frame.

This yellow pine sometimes attains a height of 150 feet and a diameter of four feet; but the pitch pine seldom exceeds two-thirds this size. The former is principally obtained from the States of Virginia, North Carolina and Georgia, while the latter is abundant in all the Atlantic States south of Chesapeake Bay. The yellow pine required for navy yard use is described as long-leaved, fine-grained Southern yellow pine. Its leaves are light green, eight to eleven inches long, and rigid; they are dark green in color. The cones are six to eight inches long.

It has but little sap wood, and the heart wood is of very uniform quality, its resinous matter being very regularly distributed. Its grain is fine and close, and it has greater strength, durability and hardness than any other species of pine.

Though not as tough and elastic as white oak, the yellow pine, especially that from Georgia, successfully rivals it in stiffness. If a beam of each kind of timber, equal in dimensions, be suspended by the ends, the oak beam will depart more from its "mould," but will break under about the same load. In dry situations the pine is extremely durable, and where the properties of lightness and solidity are required in combination it is to be preferred to oak.

The Locust or common Acacia (*Robinia pseudo-acacia*) is a flowering tree, found in the mountainous and hilly portions of the country from Canada to the Southern States.

It grows rapidly and reaches a height of seventy feet with a diameter of four feet, but is usually considered full grown if forty feet high and a foot in diameter. It is a fine ornamental tree.

The wood has a peculiar greenish-yellow color, resembling boxwood slightly. The structure is alternately very compact and quite porous. Its annual rings are thus very distinctly marked.

It exhibits no medullary rays, and the wood has neither taste nor odor. When of good quality it is difficult to cut and work. It is a very valuable timber.

It is especially valued for fence posts and rails, or boarding, but is seldom found of sufficient size and in quantity sufficient to be used in the latter form. It turns well in the lathe and has great torsional strength and resilience, excelling all other common woods in this quality.

The Ash (*Fraxinus excelsior*) *of Europe and the White Ash* (*Fraxinus Americana*) of America are also valuable timber trees. Their woods have many useful applications. Ash is quite similar in color to oak and in texture to chestnut. It is straight-grained, remarkably tough and elastic, excelling all other common woods, and answers admirably for handspikes, heavy oars, ship blocks, tool handles, the wooden portions and framing of machinery, and for wheel carriages and agricultural implements. It is durable under cover, but decays rapidly if exposed to the weather. The tree grows to a height of sixty feet, and acquires a diameter of twenty inches in rich, moist, loamy soil. It has no observable sap wood.

The Black Walnut (*Juglans nigra*) is found throughout our Middle and Western States, and as far south as the Gulf of Mexico. The tree presents a fine appearance, attains considerable size, and yields a much-prized timber.

The wood varies considerably in quality. It is of a brown color, approaching red in some specimens, and of a dark chocolate color in others. The sap wood is frequently quite light in color. The best wood has a fine grain and a dense structure, although usually excelled in both particulars by good mahogany.

It is strong, durable and easily worked. It is more generally used in the United States for furniture and for ornamental purposes than any other wood, and immense quantities of it are annually worked up. It is nearly as strong as mahogany and is tougher.

The Live Oak (*Quercus virens*) is one of the best known ship-timber trees. It is evergreen and grows on the seacoast from Maryland to the Gulf of Mexico and the Mississippi, and is now so scarce and so valuable that the government has reserved all of the Florida live oak forests for naval purposes.

This timber is used almost exclusively for the purposes of ship

building. It is heavy, compact, fine-grained, yellowish in color, and is the strongest and most durable of all American woods.[2]

The tree grows to a height of sixty feet, and to a diameter of four feet, but is usually forty or forty-five feet high and twelve to eighteen inches in diameter. The capillary vessels of the heart wood are filled with a gummy substance; unlike other varieties of oak in our country, it is free from acid.

Live oak is not well adapted to the reception of spike fastenings, as the grain refuses to receive the point in the cutting direction, and permits splitting of the wood. There is no difficulty, however, in fastening with bolts and tree-nails. The sap wood is whitish in color, and is free from the glutinous matter found in the dense heart wood. Live oak, if exposed long in the open air, in the rays of the sun, or to winter winds, will crack badly. It does not require many months of air-seasoning, however, to fit it for its ordinary uses. It is the most costly ship timber in the market.

The White Oak (*Quercus alba*) is a more common and a very valuable variety, and is in extensive use, especially for ship building, for which its trunk furnishes the heavier timber, and its large roots and branches yield "compass timber." It is used for water-wheel shafts and other millwrights' work. The bark is of great value for tanning.

This tree is found from Canada to the Carolinas, and is most abundant in the Middle States, forming large forests west of the Alleghany range of mountains. It reaches a height of eighty feet and more, and its trunk is sometimes six or seven feet in diameter. It is one of the few trees which retain any of their leaves throughout the winter. The leaf is deeply indented, long and narrow. Its bark is of a light grayish-white color, giving it its name; its wood is light straw colored, with a tinge of red, and is very tough, strong, durable, elastic and pliable, with strong lateral cohesion. It is very liable to shrink, warp and crack in seasoning, and is therefore of little value for boards. It is used for artillery carriages and makes very good steps for the lower ends of turbine water-wheel shafts. The shrinkage in seasoning amounts to about $\frac{1}{32}$.

The wood of trees sixty to one hundred years of age is much

[2] The writer possesses a live oak cane taken in 1865 from the keel of the frigate *United States*, a naval vessel built very early in the present century. It is as perfectly sound, apparently, as when first cut.

tougher, particularly on high lands, than that of older trees. The wood from the roots makes beautiful furniture. The cost and the difficulty of working it preclude its extensive use. No certain data exist for comparing the properties of white oak grown in various districts, but it is generally supposed that the best timber for durability is that grown near the Atlantic seaboard or along the borders of the great lakes. Generally the strongest timber is grown on wet lands.

It has a specific gravity of from 0·7 to 1·1, weighing from forty-four pounds dry to seventy pounds when green per cubic foot.

THE FORM AND DIMENSIONS OF TEST-PIECES used in these experiments (see Figs. 1 to 4) were, as at first prepared, given in the accompanying figures:

FIG. 1. Tension.

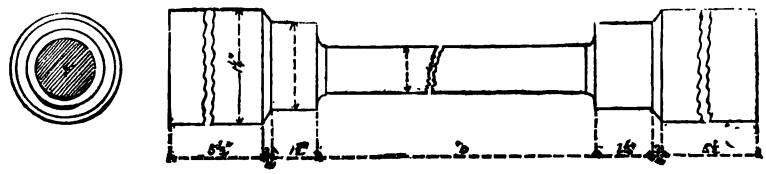


FIG. 2. Compression.

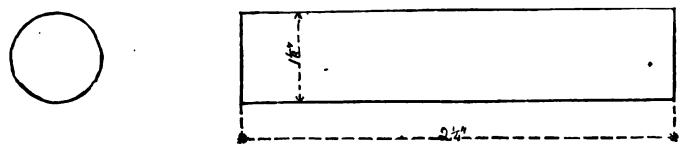


FIG. 3. Transverse.

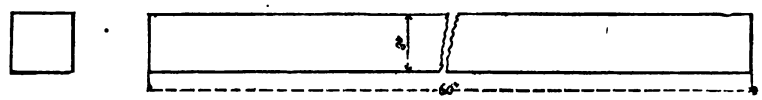
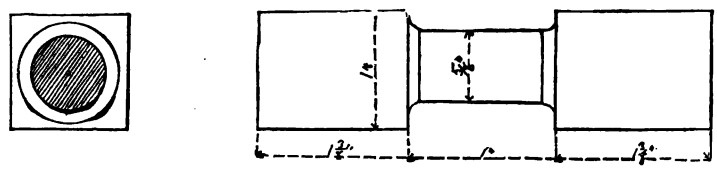


FIG. 4. Torsion.



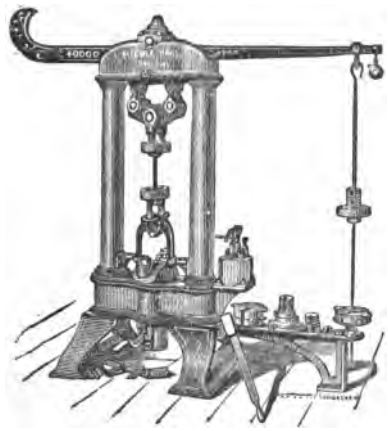
The following table exhibits their sizes and densities:

TABLE OF DIMENSIONS AND DENSITIES OF WOODS.

NAME.	No. 1. Tension.		No. 2. Compression.		No. 3. Transverse.				No. 4. Torsion.		Weight per cubic inch in pounds.	Weight per cubic foot in pounds.
	Length.	Diameter.	Length.	Diameter.	Length.	Breadth.	Depth.	Distance between supports.	Length.	Diameter.		
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
White Pine,	4	·537	2·25	1·117	60	3	3	54	1	·780	·0017	29·376
Yellow Pine,	4	·532	2·25	1·102	60	3	3	54	1	·760	·0270	46·656
Locust,	4	·522	2·25	1·078	60	3	3	54	1	·656	·0330	57·024
Black Walnut,	4	·535	2·25	1·112	60	3	3	54	1	·785	·0220	38·016
White Ash,	4	·544	2·25	1·104	60	3	3	54	1	·762	.0200	34·560
White Oak,	4	·481	2·25	1·117	60	3	3	54	1	·780	·0240	41·472
Live Oak,	4	·497	2·25	1·117	60	3	3	54	1	·656	·0390	67·392

THE TESTING MACHINES used in this work were the standard machines of the Mechanical Laboratory of the Stevens Institute of Technology. The tension and compression machine is of a peculiar design, which has never been reproduced, and which was supplied to the writer by Messrs. Riehlé Bros., of Philadelphia. The capacity of the machine is twenty tons. Fig. 5 exhibits the machine with sliding poise and adjusting apparatus omitted.

FIG. 5.



The extensions were measured by means of an instrument in which contact is indicated by an "electric contact apparatus." The instrument consists essentially of two very accurately made micrometer screws, working snugly in nuts secured in a frame which is fastened to the head of the specimen by a screw clamp. It is so

shaped that the micrometer screws run parallel to and equidistant from the neck of the specimen on opposite sides. A similar frame is clamped to the lower head of the specimen, and from it project two insulated metallic points, each opposite one of the micrometer screws. Electric connection is made between the two insulated points and one pole of a voltaic cell, and also

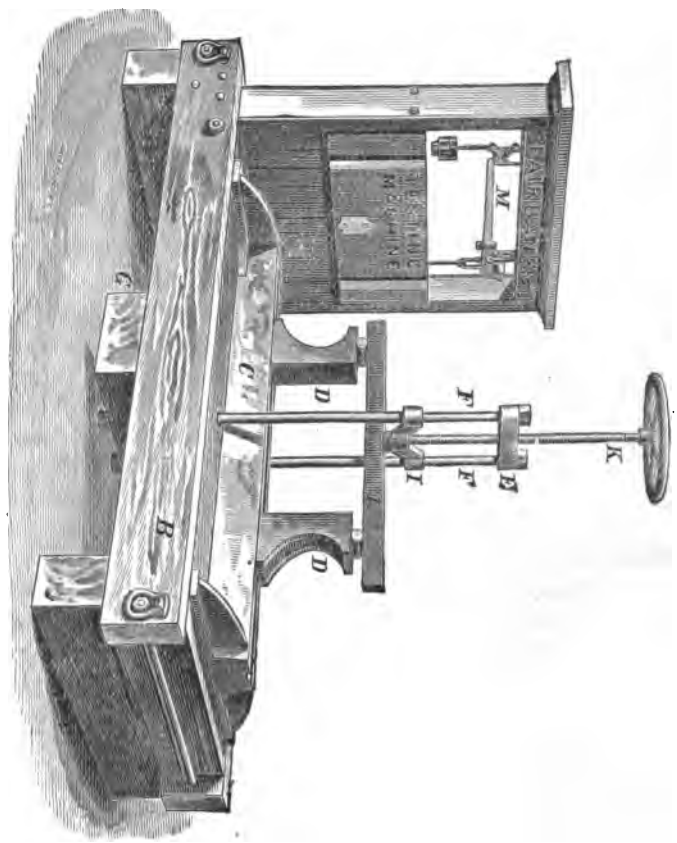


FIG. 6.

between the micrometer screws and the other pole. As soon as one of the micrometer screws is brought in contact with the opposite insulated point a current is established, which fact is immediately revealed by the stroke of an electric bell placed in the circuit. The pitch of the screws is 0·02 of an inch, and their heads are divided into 200 equal parts; hence a rotary advance

proportional to the torsional moments exerted by the weighted arm, $B\,D$, while moving up an arc, to which the corresponding abscissas of the curve are proportional, is secured to the frame, $A\,A'$. The pencilholder is carried on this arm, $B\,D$, and as the latter is forced out of the vertical position, the pencil is pushed forward by the guide curve, its movement being thus made proportionate to the force which, transmitted through the test-piece, produces deflection of the weighted arm. This guide-line is a curve of sines. The other arm, $C\,E$, carries the cylinder, G, upon which the paper receiving the record is clamped, and the pencil makes its mark on the table thus provided. This table having a motion, relatively to the pencil, which is precisely the angular relative motion of the two extremities of the tested specimen, the curve described upon the paper is always of such form that the ordinate of any point measures the amount of the distorting force at a certain instant, while its abscissa measures the distortion produced at the same instant.

The later and improved form of machine, as now built and used in the Mechanical Laboratory of the Institute, is shown in the accompanying engraving, Fig. 9.

The frames, $A\,A'$, are bolted to a heavy bed-plate, which secures the required stability. The worm wheel, M, engaging with the worm, L, has been substituted for the arm, $C\,E$; the worm is set in motion by means of the crank, L, and in this manner a very slow and quite uniform motion can be obtained. Both wrenches are provided with lathe-centres directly opposite each other and in the common axis of rotation. The specimen to be tested is placed upon the lathe-centres, which hold it in line while it is being secured in the jaws of the wrenches by means of steel wedges inserted from opposite sides.

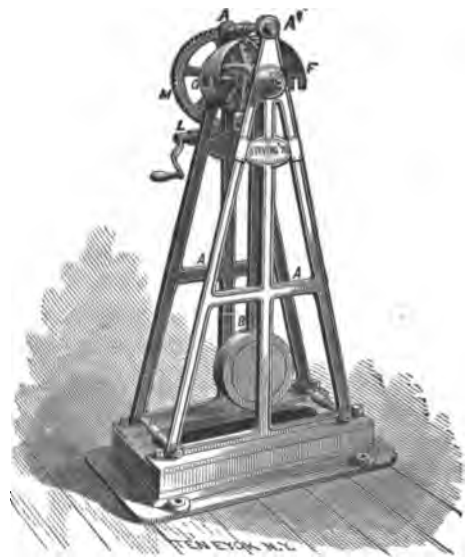
Supposing a test-piece to be placed in the machine; the operator turns the crank, L, with a uniform velocity which gives a slow and a very steady motion to the wrench connected with the worm wheel, which is transmitted through the test-piece to the wrench carrying the weighted arm. The latter is moved by the force transmitted through the test-piece through an arc, which is a measure of the resistance to torsion offered by the test-piece, and is recorded simultaneously with the angle of torsion by the pencil, as explained above.

The drum carrying the record sheet is of such a diameter that

the circumference is 36 inches, which, when divided into tenths, makes 360 divisions, each of which is representative of one degree.

In the machines employed in the Mechanical Laboratory of the Stevens Institute of Technology each inch of ordinate denotes 100 foot-pounds of moment to have been transmitted through the test-piece, and each inch of abscissa indicates 10 degrees of torsion. The friction of the machine is not recorded by the machine, but is added in calculating the results.

FIG. 9.



By means of this machine the metal tested is compelled to tell its own story, and to give a permanent record and graphical representation of its strength, elasticity and every other quality which is brought into play during its test, and to exhibit its characteristic peculiarities.

The machine first described was selected for use in this research and was altered to meet the special requirements of the case. The lever arm, even without the weight, giving too great a moment of resistance for some specimens of wood of the usual diameter, a counterpoise was arranged, consisting of a bar of iron bent to a rectangular shape and clamped to the lever arm below the guide

curve, of such a size that, when the lever arm was deflected, it would not interfere with the guide curve. To the top of this rectangle was fastened a vertical iron rod, to which was attached a weight by means of a set screw, so arranged that the continuation of the vertical axis of the lever arm should coincide with the vertical axis of the rod and weight.

In the diagrams produced by the machine thus modified, every inch of ordinate represents 1·058 ft-lbs. plus the friction of the machine, which in this case is equal to ·52 ft-lbs.; the horizontal scale is the same as above, *i. e.*, one inch of abscissa equals 10 degrees of twist.

THE EXPERIMENTS were made, as stated, in the Mechanical Laboratory of the Stevens Institute of Technology. The immediate charge of the machines and the observation of results of tests were intrusted to Mr. Frank P. Jones, M. E. (Class of '78), to whose care, skill, industry and persistence we are indebted for a series of very valuable determinations.

The results were tabulated by Mr. Jones, who, under the direction of the writer, also prepared a series of curves graphically representing them. The whole investigation was fully described in a graduating thesis.[5] The tables here given are usually presented with little or no material alteration as calculated by Mr. Jones for his thesis.

The tension-tests gave the following results:

RESULTS OF TESTS BY TENSIONS.

WOOD.	l	d	Modulus of Rupture.	Modulus of Proof Stress.	Resilience.		EXTENSIONS. Per ct. of length.	
					Ultimate.	Elast'c.	Total.	At elastic lim.
	in.	in.					in.	in.
White Pine.....	4	·527	6877·5	3900	2467·5	720·0	·725	·400
Yellow Pine.....	4	·532	20702·0	13200	21457·0	3940·0	1·650	·625
Locust.....	4	·522	2892·52	19200	31170·0	10792·5	1·850	1·100
Black Walnut.....	4	·535	9786·4	5700	4022·5	1530·0	·850	·525
White Ash.....	4	·544	15490·5	97000	12695·0	3855·0	1·475	·775
White Oak.....	4	·481	13207·8	8100	7500·0	3022·5	1·300	·770
Live Oak.....	4	.497	10309·2	6300	5887·5	2167·5	1·150	·575

[5] "Strength of Woods used in Engineering." By Frank P. Jones, M. E., '78. MSS; small 4to; pp. 75; folding plates xvii. Library Stevens Institute of Technology. 1878.

In calculating the results of tension-tests, as presented in the table, the *Resilience* was obtained, as in all other cases, by first plotting the results of test and obtaining a curve of which the ordinates measure loads and the abscissas the corresponding stretch or other form of distortion, then measuring the total area of the curve to obtain a measure of total resilience, or shock-resisting power, and by taking the area within the ordinate at the elastic limit as the measure of the elastic resilience.[6]

The Modulus of Rupture is measured by $R = \frac{P}{K}$; in which P is the load producing rupture, K is πr^2, the sectional area at the point of fracture, and R is the modulus.

The Modulus of Proof Stress is similarly obtained, taking for P the load producing permanent distortion, as measured at the elastic limit.

The calculations relating to compression were similarly made, assuming that the laws affecting wood under compression are the same as those acting when it is broken by tension — a practically correct assumption where the test pieces, as in this case, are crushed without lateral flexure.

THE RESULTS OF TEST BY COMPRESSION are presented in the following table:

RESULTS OF TESTS BY COMPRESSION.

WOOD.	l	d	Modulus of Rupture.	Modulus of Proof Stress.	RESILIENCE.		COMPRESSION. Pr. ct. of length.	
					Ultimate.	Elast'c.	Total.	At elastic limit
	in.	in.						
White Pine.....	2·25	1·117	9592·6	5600	19542·6	3534·3	3·498	1·584
Yellow Pine.....	2·25	1·102	11952·3	7000	16575·56	4107·18	2·906	1·485
Locust.....	2·25	1·073	14818·9	9800	26551·14	5761·14	3·300	1·617
Black Walnut....	2·25	1.112	7001·7	5700	5382·6	1561·56	1·254	·528
White Ash.....	2·25	1·104	8148·3	5280	12788·16	1898·82	2·310	·726
White Oak.....	2·25	1·117	7143·5	5600	15868·8	3940·86	3·300	1·551
Live Oak.....	2 25	1·117	10409·2	6300	23150·82	3100·02	3·366	1·056

THE TESTS BY TRANSVERSE STRESS gave results which are exhibited in the succeeding table. Here the modulus of rupture is

[6] The resilience, as usually defined, is *elastic* resilience; it should be carefully distinguished from *total* resilience. The one is proportioned to the *work*, or the *vis viva*, required to produce permanent distortions; the other measures the work required to produce fracture.

$R = \frac{3}{2}\frac{Pl}{bd^2}$; in which expression P = load producing rupture; l = the length of the test-piece between supports; b = its breadth; d = its depth; all measures are in inches, and loads in pounds.

In determining the Modulus of Proof Stress the same expression is used, taking for P, however, the proof load, or the load at the real or assumed elastic limit.

The Elastic and the Ultimate Resiliences here given are the number of foot-pounds of work done in straining the specimens tested to the elastic limit and to the point of rupture respectively, and may be taken as approximate measures of the shock-resisting power of the material.

The Modulus of Elasticity, or the relation of the amount of distortion to the load producing it is determined by the expression: $E = \frac{P l^3}{48 \Delta I}$, in which P is the load corresponding to a deflection, Δ, midway between supports; l is the length from support to support; Δ is the amount of deflection, and I the moment of inertia; for these rectangular sections, $I = \frac{bx^3}{12}$.

RESULTS OF TESTS BY TRANSVERSE STRESS.

WOOD.	l	b	d	Modulus of Rupture.	Modulus of Proof Stress.	Modulus of Elasticity.	RESILIENCE.		DEFLECTION.	
							Ultimate.	Elastic.	Ultimate.	At elastic lim.
	in.	in.	in.						in.	in.
White Pine,	54	3	3	5280	4320	883636	1364·8	634·8	1·28	·86
Yellow Pine,	54	3	3	16740	12720	3534727*	4174·4	2039·6	1·96	·84
Locust,	54	3	3	13680	8400	2046315	4843·2	1259·2	2·70	·82
Black Walnut,	54	3	3	7440	5640	1944000	971·6	433·2	·72	·50
White Ash,	54	3	3	9720	6360	1080000	533·3	1212·6	2·50	1·50
White Oak,	54	3	3	9840	7200	1620000	3660·8	1227·2	1·76	·90
Live Oak,	54	3	3	11280	9040	1851428	4601·6	1462·4	1·38	·94

TESTS BY TORSION were made in the Autographic Machine, modified as already described.

Elasticity is measured by $E = \frac{r}{h}$, in which r is the measure of the recoil on removal of the load, and h the measure of the stress on the diagram taken from base-line.

Stiffness is measured by $S = \frac{m}{o}$, in which o measures the angle

*This figure is about double that usually obtained.

of torsion to the point considered (within the elastic limit), and m the value of the corresponding ordinate.

The Modulus is obtained by the expression $E = \frac{ml}{oh^5}$, in which m and o have the values assigned above; l = length of neck of test-piece, and h = its diameter.

The Resiliences, elastic and ultimate, come from the expressions $e = a\frac{m}{R} + F\frac{l}{R}$, and $E = A\frac{m}{R} + E\frac{l}{R}$, in which a is the area of curve to the elastic limit; A is its total area; l = length of abscissa; R = radius of the drum carrying the sheet; m = foot-pounds per square inch of area of curve.

RESULTS OF TESTS BY TORSION.

WOOD.	l	d	RESILIENCE.		Stiffness.	Elastic Modulus of Resistance to Torsion.
			Ultimate.	Elastic.		
	in.	in.				
White Pine,.....	1	·780	5·10	·235	·443	1·534
Yellow Pine,.....	1	·760	12·425	·238	1·744	6·878
Locust,.....	1	·656	14·067	·178	1·720	14·159
Black Walnut,.....	1	·785	7·396	·238	1·088	3·050
White Ash,.....	1	·762	7·381	·560	·598	2·328
White Oak,.....	1	·780	12·777	·396	·911	3·155
Live Oak,.....	1	·656	14·570	·631	·474	3·902

COMPARING AUTHORITIES on the strength of woods, it will be found that the results here recorded usually differ from those obtained by earlier experimenters, and that these figures are almost invariably higher than those of Barlow, Tredgold or Laslett, a fact probably attributable to the very uniform excellence in quality of the specimens tested, although it is possible that they may prove the superiority of the American to the European timber.

The American timber, as here tested, gives figures in tension from one-eighth to one-fourth higher than the European woods reported on by Barlow or Tredgold, with the exception of ash. Tredgold's figures for American woods are, however, lower than those here presented, which is evidence of a difference in quality of test-pieces rather than of differences in the varieties of timber. The tables of resistance of timber given in Wood's "Resistance of Materials" accord more closely with those here obtained than

do those given frequently elsewhere; they are, however, usually lower than these.

Comparing the results of torsional tests with those previously obtained by the writer,[7] by a similar method, they were found substantially to agree. The later experiments of Mr. Jones do not exhibit the peculiar phenomenon of a depression and subsequent re-elevation of the curve of the strain diagram which is exhibited in some cases in the earlier records. This may be due to the more complete seasoning of the test-pieces last used, or to the action of the modified machine, which was less free from friction, and therefore somewhat less sensitive than was that first used by the writer.

In all cases the test-pieces here described were prepared from selected wood, straight-grained, free from knots or other perceivable defect, and may probably be considered as representative of the best quality of American timber, with the exception of the specimen of pine already mentioned. They were measured, when brought to size, by callipers, reading to $\frac{1}{1000}$th inch.

Results were carefully corrected for the local crushing of the wood at points of contact with the machine.

The characteristics of the several woods are best shown by the autographic strain diagrams, of which two sets were given. The one giving the line of recoil when the load was removed at the elastic limit, the other exhibiting the full curve up to the point of final rupture. The areas of these curves were measured very carefully, by using an excellent planimeter reading to $\frac{1}{100}$th square inch.

American timber has, apparently, a value, in construction, equal, if not decidedly superior to, European timber.

The strength of American timber, as given by earlier authorities, is probably that of average specimens, and timber may be obtained, as in this case, by careful inspection of very much greater value.

Timber yields, under all forms of stress, to an extent which may be taken, as with cast iron, to be proportional to the load.

From what is above stated, and from a study of the strain diagrams, it may be concluded that the strength of timber is so variable that the only safe course in construction is to assume the

[7] "On the Strength, Elasticity, Ductility and Resilience of Materials of Machine Construction, etc." Trans. Amer. Soc. of C. E., JOURNAL OF THE FRANKLIN INSTITUTE, 1874.

highest values, determined by the most uniform series of tests of the material proposed to be used, and then to adopt a high factor of safety.

The tables above given may probably be taken to represent the probable values of resistance of the best selected woods, such as are passed by inspectors for naval purposes.

[NOTE.—For the complete paper see the Journal of the Franklin Institute for November, 1879.]

TITLES OF OTHER PAPERS READ IN SECTION A.

METEORIC CONSTITUTION OF THE SIDERIAL UNIVERSE: I. COOLING OF THE SUN. II. COOLING OF THE EARTH. By Benj. Peirce, of Cambridge, Mass.

ON A STANDARD METER AND ITS SUBDIVISION INTO EQUAL PARTS. By William A. Rogers, of Cambridge, Mass.

ON THE COEFFICIENT OF EXPANSION OF NICKEL-PLATED BARS. By William A. Rogers, of Cambridge, Mass.

ON THE TREMORS COMMUNICATED TO TRANSIT PIERS AND DOCK PIERS THROUGH THE WALLS OF AN OBSERVATORY BUILDING. By William A. Rogers, of Cambridge, Mass.

ON THE USE OF GLASS CIRCLES FOR MERIDIAN INSTRUMENTS AND OF GLASS BARS FOR STANDARDS OF LENGTH. By William A. Rogers, of Cambridge, Mass.

THE COMET OF 1771. INVESTIGATION OF ITS ORBIT. By William Beebe, of New Haven, Conn.

SOME OBSERVATIONS ON THE DEPTH OF SNOW COMPARED WITH THE DEPTH OF THE WATER IT YIELDS. By John Brocklesby, of Hartford, Conn.

STATEMENT OF GENERALIZATION REACHED IN QUESTION IN INTERSECTION OF CIRCLES AND INTERSECTION OF SPHERES: RESULTS STATED, NOT THE GEOMETRICAL DISCUSSION. By Benj. Alvord, of Washington, D. C.

ON A TRIGONOMETRICAL VIEW OF THE CALCULUS. By John Trowbridge, of Cambridge, Mass.

THE RELATION BETWEEN CONTINENTAL OUTLINES AND TERRESTRIAL MAGNETISM. By Richard Owen, of New Harmony, Ind.

A GENERAL LAW INDICATING THE LOCATION OF PLANETS, SATELLITES, OR ANNULAR RINGS AROUND THEIR PRIMARIES. ALSO ITS UTILITY. By Samuel Marsden, of St. Louis, Mo.

A TABLE OF REMAINDERS OF 2^N TO VARIOUS PRIME MODULI. By E. P. Austin, of Boston, Mass.

ON EXPLOSIVE AND DETONATING COMPOUNDS. By Benjamin S. Hedrick, of Washington, D. C.

THE PAST STATE OF THE WORLD'S METROLOGY AS BEARING ON THE PROGRESS OF SCIENCE. By F. A. P. Barnard, of New York, N. Y.

NEW METHODS OF PHOTOMETRY AS APPLIED TO ELECTRIC LIGHT. By P. H. Van der Weyde, of New York, N. Y.

A SURFACE UPON WHICH THE "NON-EUCLIDEAN GEOMETRY" FINDS ITS INTERPRETATION. By A. W. Phillips, of New Haven, Conn.

MODIFICATION OF THE GLASS-PLATE POLARIMETER. By A. W. Wright, of New Haven, Conn.

INFLUENCE OF LIGHT ON THE ELECTRICAL CONDUCTIVITY OF METALS. By A. W. Wright, of New Haven, Conn.

UPON THE METHODS OF EXPLORING THE FIELD OF INDUCTION OF FLAT SPIRALS. By A. G. Bell, of Boston, Mass.

UPON RESIDUAL INDUCTION. By A. G. Bell, of Boston, Mass.

UPON BINAURAL AUDITION. By A. G. Bell, of Boston, Mass.

A STUDY: FORMS OF ENERGY. By J. D. Warner, of Brooklyn, N. Y.

The three following papers were presented at General Sessions:—

ON THE ELECTRO-CHEMICAL TELEPHONE. By Thomas A. Edison, of Menlo Park, N. J.

NOTICE OF A CATALOGUE OF SCIENTIFIC SERIALS. By Samuel H. Scudder, of Cambridge, Mass.

ON THE OPERATION OF THE SCIENCE AND ART DEPARTMENT OF THE PRIVY COUNCIL OF GREAT BRITAIN. By James Samuelson, of London.

PERMANENT

SUBSECTION OF CHEMISTRY.

ADDRESS

OF

PROFESSOR IRA REMSEN,

CHAIRMAN OF THE SUBSECTION OF CHEMISTRY.

GENTLEMEN OF THE SUBSECTION OF CHEMISTRY:—

AT this season of the year, when most of us have for a time turned our backs on the small, artificial laboratories, which form our homes, and are seeking relaxation and enjoyment in the great laboratory of Nature; and when the simple thought of a chemical reagent is almost sufficient to cause a strong mental reaction, it is especially difficult to find a theme for an address which shall prove interesting and instructive to those who hear it. And yet in comformity to the custom of this body I propose to take advantage of the opportunity which you have kindly given me to speak to you on some subjects which have long been on my mind—subjects, a consideration of which may not, I hope, be entirely uninteresting to us all as chemists.

Assuming that I owe my election to the chairmanship of this section to what little work I have been able to do to further the advancement of our common science, and knowing that this work has been mainly in the field of organic chemistry, my thoughts naturally turn to this field at the present time, and I would ask you to turn your thoughts for a brief period in the same direction, while I attempt to point out certain important relations — well known to be sure, but often lost sight of — which exist between

what is commonly called organic chemistry, and chemistry proper in its broadest sense. By organic chemistry I mean, of course, what is better called the chemistry of the compounds of carbon, but for the sake of convenience I shall use the shorter and better known expression.

Let me, at the outset, say distinctly that I do not regard organic chemistry as the one important part of chemistry, but only as *an* important part. I do not believe in magnifying the importance of one part of the science to the detriment of any other part. I regard the whole science of chemistry as a unit to be mastered by him who is to be called chemist; and no man is worthy of the name of chemist who has not familiarized himself with the main facts and the underlying principles of the whole science.

Organic chemistry bears essentially the same relation to the science, as a whole, as, for instance, the chemistry of the compounds of sulphur, of iron, or of sodium. There is nothing more mysterious and inexplicable connected with compounds of carbon than with other chemical compounds. They undergo the same kinds of change, they obey the same laws, they are only chemical compounds. No chemist who is acquainted with the results of modern investigations will deny the truth of these statements.

Nevertheless, it may be asserted with confidence that in nearly all the educational institutions in this country, organic chemistry, as a branch of study, is sadly neglected. This is not only true of those institutions in which the study of chemistry is necessarily of minor importance, but also of those in which chemistry is taught as a specialty. There are, of course, some noteworthy exceptions, but these are not numerous enough to destroy the force of the statement. I can hardly expect that my simple assertion will carry conviction with it, and I do not desire that it should. We have to deal with a question of fact which can be examined in the abstract. And, though it is difficult to present perfectly satisfactory evidence either for or against the assertion, I think that an unprejudiced investigation will prove that it is true.

Every one who has had much experience in the examination of the catalogues of colleges and universities knows that in the case of most of them a liberal allowance must be made for exaggeration which may be the result of the enthusiasm either of loyalty or of ignorance. For this reason, I do not consider it important

to give a detailed account of the results of an examination of these sources of information, and I will simply remark in passing, that, while in some important institutions it is found that an appreciable quantity of time is devoted to the study of our subject, in others there is scarcely a mention of its existence. The announcements in some of these catalogues would tend to engender in the minds of beginners the entirely false and pernicious notion that analytical chemistry is the main subject of study for the chemist — a notion, by the way, too often held by those who, unfortunately, are called upon to instruct.

Then again, it is quite impossible to determine exactly what is meant by the announcements made in any catalogue. The same expressions may, in different cases, mean entirely different things, and yet both be correct as far as they go. The simple statement in a catalogue, that organic chemistry is actually taught for a third, a half or a whole year in a course especially designed for chemists, would not afford evidence that the subject is not neglected. The main questions are: How is it taught? And what are the results of the teaching?

Any evidence then based upon statements made in these catalogues is likely to be deceptive to a greater or less extent.

The most conclusive evidence of the correctness of my assertion that organic chemistry is neglected in our country is presented by the graduates of our educational institutions. During the past ten years, I have made the acquaintance of a large number of these graduates, some of whom had completed the prescribed courses in well known institutions in this country in which science is specially taught. Among them were also some who had been honored with appointments as instructors in chemistry in their own colleges. And I have yet to meet one who possesses anything like a systematic and comprehensive knowledge of the subject of organic chemistry. I do not mean by this a masterly knowledge, such as few, under the most favorable conditions, attain, but such knowledge as half the American students of chemistry who go to Germany to study are sure to acquire in a short time under the influences there surrounding them. Too often it happens that the student, after having completed a prescribed course in any branch of study, concludes from this fact that he has a thorough knowledge of the branch, and afterwards neglects opportunities which may present themselves to perfect his knowledge. Just as

a child, who is allowed to read too much Shakspeare, not to mention better books, in his early years, fancies after maturity is reached that he is familiar with the books over which with imperfect comprehension he has spent much time. So that the statements of students as to their own acquirements, like the statements of college catalogues, require further verification.

I recall in this connection some curious instances illustrating this subject. Not long ago a student came to me desiring, for special reasons, to be examined in chemistry. He was a graduate of a prominent institution, had distinguished himself as a student, and was regarded by his instructors as one of their best products. In the course of a brief conversation, I asked among other things whether he had received any instruction in organic chemistry. He answered in the affirmative, and at once proceeded spontaneously to give me some idea of his attainments in the subject. He said he had made a careful study of albumen, fibrine, protagon, the substances which occur in the bile, and a number of other similar compounds found in the animal body, and he thought he understood them very well. This was his idea of organic chemistry. The simplest facts which serve to characterize the compounds of carbon and give us an insight into their nature were entirely unknown to him. Another young man who had been an instructor of chemistry in a very influential school of science recognized in quinine, nicotine, morphine and other alkaloids, not only the essential parts of the plants in which they are found, but the essential, active principles of organic chemistry. "If we only understood these substances," said he, "the whole subject of organic chemistry would be clear to us." I discovered afterwards that this alkaloid-worshipper had never grasped a single general principle underlying the facts of organic chemistry. I could easily increase the number of illustrations, and could show that the two cases mentioned are by no means exceptional. The young men referred to were rather more than ordinarily intelligent, and subsequent experience with them showed that the perverted notions with which they presented themselves to me at first were certainly the result of their previous training, and not of mental incapacity.

Again, I have not unfrequently met American students in Germany who, while wishing to make chemistry their profession, objected to studying organic chemistry at all. They regarded the

subject with a sort of contempt. When asked why they objected to the study, the answer was almost invariably: "The Professor under whom I studied at home advised me to spend my time in acquiring something more important." The "something more important" usually turned out to be analytical methods.

Of course, when students are found with radically wrong ideas, the blame in most cases attaches itself to their instructors, and while students have been used as examples, they serve mainly to show that there is a more fundamental difficulty and that is in the instructors themselves. Prominent professors of chemistry might be named who either speak slightingly of organic chemistry, or, at least, by their teachings serve to spread the idea that chemistry is divisible into two parts, one of which is chemistry proper, while the other is an almost superfluous attachment which, if time permit, it is well enough to look into, but which may also be omitted entirely from serious consideration without much harm. Although this attitude of the gentlemen referred to can usually be traced back to the fact that they have very little comprehension of the subject, still this only serves to indicate the truth of my original assertion that organic chemistry is neglected among our chemists.

I propose then to show that the relations of organic chemistry to chemistry are such, that the subject must necessarily be taught, and taught thoroughly to those who are to understand chemistry as it is at present.

In the first place, many of the important modern changes in the science of chemistry have been brought about by investigations of the phenomena presented by various compounds of carbon. Entirely new conceptions have been introduced into the science by these investigations. Hence the question: How did chemistry come to be what it is? can not be answered without constant reference to studies upon the compounds of carbon. Whatever may be the intrinsic value of the conceptions of *substitution*, *isomerism*, *valence*, *structure*, it cannot be denied that these conceptions do at present play exceedingly important parts in the science. Their full significance, their relative importance, can not be comprehended by one who has not made some study of the historical development of these ideas; and without a knowledge of the compounds of carbon this study of the historical development can not be made.

a child, who is allowed to read too much Shakspeare, not to mention better books, in his early years, fancies after maturity is reached that he is familiar with the books over which with imperfect comprehension he has spent much time. So that the statements of students as to their own acquirements, like the statements of college catalogues, require further verification.

I recall in this connection some curious instances illustrating this subject. Not long ago a student came to me desiring, for special reasons, to be examined in chemistry. He was a graduate of a prominent institution, had distinguished himself as a student, and was regarded by his instructors as one of their best products. In the course of a brief conversation, I asked among other things whether he had received any instruction in organic chemistry. He answered in the affirmative, and at once proceeded spontaneously to give me some idea of his attainments in the subject. He said he had made a careful study of albumen, fibrine, protagon, the substances which occur in the bile, and a number of other similar compounds found in the animal body, and he thought he understood them very well. This was his idea of organic chemistry. The simplest facts which serve to characterize the compounds of carbon and give us an insight into their nature were entirely unknown to him. Another young man who had been an instructor of chemistry in a very influential school of science recognized in quinine, nicotine, morphine and other alkaloids, not only the essential parts of the plants in which they are found, but the essential, active principles of organic chemistry. "If we only understood these substances," said he, "the whole subject of organic chemistry would be clear to us." I discovered afterwards that this alkaloid-worshipper had never grasped a single general principle underlying the facts of organic chemistry. I could easily increase the number of illustrations, and could show that the two cases mentioned are by no means exceptional. The young men referred to were rather more than ordinarily intelligent, and subsequent experience with them showed that the perverted notions with which they presented themselves to me at first were certainly the result of their previous training, and not of mental incapacity.

Again, I have not unfrequently met American students in Germany who, while wishing to make chemistry their profession, objected to studying organic chemistry at all. They regarded the

subject with a sort of contempt. When asked why they objected to the study, the answer was almost invariably: "The Professor under whom I studied at home advised me to spend my time in acquiring something more important." The "something more important" usually turned out to be analytical methods.

Of course, when students are found with radically wrong ideas, the blame in most cases attaches itself to their instructors, and while students have been used as examples, they serve mainly to show that there is a more fundamental difficulty and that is in the instructors themselves. Prominent professors of chemistry might be named who either speak slightingly of organic chemistry, or, at least, by their teachings serve to spread the idea that chemistry is divisible into two parts, one of which is chemistry proper, while the other is an almost superfluous attachment which, if time permit, it is well enough to look into, but which may also be omitted entirely from serious consideration without much harm. Although this attitude of the gentlemen referred to can usually be traced back to the fact that they have very little comprehension of the subject, still this only serves to indicate the truth of my original assertion that organic chemistry is neglected among our chemists.

I propose then to show that the relations of organic chemistry to chemistry are such, that the subject must necessarily be taught, and taught thoroughly to those who are to understand chemistry as it is at present.

In the first place, many of the important modern changes in the science of chemistry have been brought about by investigations of the phenomena presented by various compounds of carbon. Entirely new conceptions have been introduced into the science by these investigations. Hence the question: How did chemistry come to be what it is? can not be answered without constant reference to studies upon the compounds of carbon. Whatever may be the intrinsic value of the conceptions of *substitution*, *isomerism*, *valence*, *structure*, it cannot be denied that these conceptions do at present play exceedingly important parts in the science. Their full significance, their relative importance, can not be comprehended by one who has not made some study of the historical development of these ideas; and without a knowledge of the compounds of carbon this study of the historical development can not be made.

the trouble to make the careful examination. The truth is that the conceptions regarding the structure of chemical compounds held at the present day by the leaders of our science rest upon as firm a foundation as our conceptions concerning the existence of atoms. Most structural formulas met with are the legitimate expressions of facts known regarding the compounds represented. A careful study of the chemistry of carbon compounds will reveal a wealth of arguments in favor of the structural formulas employed; but the subject must be studied systematically and carefully before the arguments can be fully appreciated. Surely we have the right to demand of the chemist that he shall study the subject systematically before he indulges in such sarcastic and frivolous criticism as has of late been heard so frequently.

Is the investigation of structure useless? Is nothing of value to be reached by following out the hundreds of painstaking researches in the region of structure, the results of which are constantly being published? Some who are preaching the cause of what is called "chemical physics" would certainly lead us to the opinions thus interrogatively expressed; but I am not prepared to go with them. And let me here state my chemical creed in a few words.

I believe that chemistry will never reach its perfect state through investigations carried on along one line.

I believe that investigations in every direction, touching every class of compounds and every variety of phenomena, should be encouraged by every possible means, and that only in this way is advancement to be made.

In accordance with these simple articles of belief, I believe that the investigations in regard to structure now going on will lead to more important results in the future than they have in the past — important as these have been; but they must, of course, be supplemented by investigations of the phenomena attendant upon chemical reactions. The study of the thermal and electrical phenomena observed in connection with chemical transformations is of undoubted importance, but this kind of study alone could never lead us very far.

But while speaking thus confidently in regard to the subject of structure, I can not and would not forget that there are those who are over-zealous in the use of structural formulas. They forget too frequently that in chemistry a formula must be the expression

of known facts, or else be almost valueless. Our formulas can not yet be used as mathematical formulas. We can not reason with them, and draw conclusions of any value with reference to things unknown. Each step must be verified by experiment, and the formulas can only express what has been established by experiment. As to the mode of expression, that must, to a certain extent, be dependent upon some fundamental hypothesis applicable in every case. At present it is held that atoms combine with atoms and that, by the property of valence, there is a definite limit to the number of other atoms with which any given atom can combine; and the facts known in regard to chemical compounds are expressed in terms of this *valence-atomic hypothesis*. But it must be remembered that the facts expressed are not dependent upon this hypothesis; and, if to-morrow another and better one should be suggested, the structural formulas now in use would have to be changed indeed, but all of them would be changed in the same way, and they would be just as valuable as they are now. The change would be simply a translation from one language to another, the statements remaining in essence the same.

With these few side remarks then concerning the general importance of the subject of structure, I return to my main theme, and repeat that the subject can not be properly comprehended without a careful study of the chemistry of carbon compounds.

The conception of valence is the outgrowth of what at one time enjoyed the name of the "theory of types." Dumas found that when acetic acid is treated with chlorine the hydrogen of the acid is partly replaced by chlorine, and that the product thus obtained is still an acid very much resembling acetic acid itself. Through a consideration of the connection existing between such bodies as acetic and chloracetic acids; between chloroform, bromoform and iodoform, etc., he was led to the idea that many compounds may be regarded as belonging to the same type, and, in a certain sense, to be derived from the typical body. One of the chief objects of investigation, after the introduction of the new "theory," was to determine to what type any given compound belonged. The classical investigations of Williamson on the "Formation of Ethers," of Würtz and Hofmann on "Substituted Ammonias," in which, by a series of brilliant experiments, it was shown that the three hydrogen atoms of ammonia can be replaced by various groups

obtained from carbon-compounds, of Cahours on "Acid Chlorides," and many others resulted in the perfection of the theory of types. It was put forth in its almost perfect form by Gerhardt in his celebrated "Traité de Chimie organique." Gerhardt supposed all chemical compounds to be built up on the model of four well-known substances, viz.: hydrogen, hydrochloric acid, water and ammonia. These were the types to which all compounds could be referred. At a later date Kekulé added a fifth typical substance, marsh gas. It was soon found that these types were insufficient, and that the "theory" was really of very little value. A more thorough examination of the typical substances showed that their existence is dependent upon the presence in them of different kinds of elements. In all of the types hydrogen is present, but the other constituent is in each case different. These other constituents are chlorine, oxygen, nitrogen and carbon. The differences in the types are due primarily to fundamental differences between the atoms of chlorine, oxygen, nitrogen and carbon. The oxygen atom can hold in combination twice as much hydrogen as the chlorine atom. The nitrogen atom can hold three times; and, finally, the carbon atom can hold four times as much hydrogen as the chlorine atom. Thus the property of atoms known as *valence* was discovered; and a step beyond the "theory of types" was taken. At the present time many of the battles of chemistry are being fought over this subject of valence. Intricate, as it apparently is, incomprehensible as it certainly is, it undoubtedly contains the germ of a much clearer idea of chemical phenomena than any one now possesses.

In the second place, it will be seen from the remarks just made that much of the work in chemistry going on at the present day is in connection with the compounds of carbon; and no one can understand the spirit of working chemists without an understanding of these compounds. Take up any one of the ten or twelve journals of chemistry published in the different countries and see what themes are occupying the energies of those who are doing something towards adding to the science of chemistry. At least three-fourths of the original work done bear directly upon the compounds of carbon, and the journals which present to the scientific world the results of this work are sealed books to those who do not understand these compounds. It is impossible for any one to read intelligently the current journals of chemistry unless

he has made a thorough study of organic chemistry; and I assert most emphatically that he who does not constantly read the journals of his science, and read them with care, can not possibly keep in the front rank of his scientific brethren. Let him cease to read the journals, let him depend upon other means for acquiring information in regard to the work going on in the laboratories of the world, and, before he knows it, he will be a veritable Rip Van Winkle in science. Should he ever wake and attempt to comprehend his surroundings he will find it as difficult as did his famous prototype.

It is a grave error committed by many chemists, that they do not read the journals. The results are apparent. If these gentlemen ever did any original work they gradually grow less and less active, and at last the delicious excitement attendant upon a successful unravelling of the mysteries of Nature becomes but a thing of memory. Pure science loses its attractions, and the duties connected with the position which may be held are performed simply in a perfunctory manner. This is no exaggeration, and the line of thought is not the result of speculation. Year after year Americans return home from Germany after having passed through complete courses in chemistry in the best universities. Of the large number who have enjoyed the best advantages, but very few ever accomplish much in the way of original work afterward. There are many reasons for this, with some of which we are more than acquainted. We have all heard how the time of our professors is completely taken up in class-room work and uninteresting details; how lacking this country is in those influences which stimulate to higher scientific work, etc. Well! there is much truth in these statements; but not enough to account for the want of activity noticed among the chemists of this country. I have nothing to say about the lack of time complained of, as that is foreign to the present discussion, but, as regards the lack of stimulating influences, I will simply say that the case is by no means hopeless, as there is nothing which exerts a more healthful, stimulating influence upon a scientific man than the reading of the journals which treat of his specialty, and I do not recall just now any very good reason why these journals should not be read. In chemistry, however, as has been remarked, it is impossible to read the journals without an understanding of the subject of organic chemistry.

Or let us turn to another side of the question, for I have no desire to be one-sided. Perhaps my practical brother objects to my way of looking at the subject. He has but very little interest in the historical development of chemistry, or in the thousand and one purely scientific investigations which he will meet with in special chemical journals. He is not engaged in original work and the reading of the journals is not necessary for him. Still I think a few brief considerations will show that the study of organic chemistry is as important for the practical chemist, as for him who follows the pure science.

What are the new branches of industrial chemistry which have been attracting attention during the last quarter of a century? Every one knows that from coal-tar numerous valuable substances are prepared, prominent among which are many of the most prized dyes. If any one should understand the chemistry of these substances it certainly is the chemist who has to do with the science mainly in its industrial aspect. Take the aniline dyes for instance. It is quite impossible to understand the composition and nature of the mother-substance of these dyes without a comprehension of some characteristic and some rather complex changes of organic compounds: and it is equally difficult to understand the formation of the numerous varieties of the dyes from the mother-substance without a knowledge of organic chemistry. To say that aniline is the amido-derivative of benzene, and that it is obtained from nitro-benzene by treatment with nascent hydrogen; that commercial aniline is a mixture of amido-benzene and two or three isomeric varieties of toluidine, would I fear sound rather unintelligible to a person who had not studied organic chemistry moderately carefully. Further, to understand the relations between rosaniline and commercial aniline requires a pretty thorough study of a large number of other relations between compounds contained in the same group. Or again, take the recently discovered phenol-dyes, chief among which is the wonderful *eosine*. What a hopeless task would be an attempt to explain its composition to one not versed in organic chemistry! In the first place, what is a phenol? Then from which phenol is eosine derived? what reaction yields it? etc. Eosine is known scientifically by the name tetrabromfluoresceine; and fluoresceine is further known as the phthaleine of resorcine. The names are perfectly comprehensible, and explain to us, if we are familiar with the general reaction be-

tween phenols and phthalic anhydride discovered by Baeyer, that fluoresceine is obtained by treating resorcine with phthalic anhydride; and that eosine is a product of the action of bromine on fluoresceine. So too with alizarine which forms the basis of a very important industry. Its chemistry is simple if one understands the general reactions, the general principles involved in its formation. Then further, the dyes from diazo-compounds which have lately become important. Who can deal with these successfully who has not read the classical papers of Griess understandingly?

There can be no doubt that in the future other important branches of industry will be founded upon results reached by work in the province of organic chemistry. Many substances now obtained only from plants at great expense are destined to be manufactured artificially. Already we have methods for the manufacture of the oil of mustard, for vanilline and other much used compounds; and there are indications that the time will come when indigo will be contained in the list of those substances which are made in the chemist's laboratory, as two methods are already known which yield it, though not in sufficient quantity to make its manufacture profitable.

While thus advocating the study of organic chemistry as a necessary part of a course in chemistry, and not merely as a luxury, I would be very careful not to let my enthusiasm for the study carry me too far, so that I should neglect the science in its broadest sense. That there is danger of this result is evident from the way instruction in chemistry is managed in some of the universities of Germany at present. In some of the university laboratories the instruction in general chemistry is unquestionably superficial, while an amount of work is done in the field of organic chemistry that is almost incredible. This method should be condemned in the strongest terms. While the results of the work done are in many cases interesting and important, the sacrifice of the student for the sake of the results should not be countenanced. I recognize very fully the importance of having a student go through with an original investigation at some period in his course of study,—indeed I regard this as an absolute necessity in a course which makes any pretensions to completeness, but I certainly would not think of putting him on such work until he has had a thorough training in general chemistry. This precaution is too often neglected in Germany. The professor is inter-

ested in the solving of some problem, and the young student, inexperienced in the science, and submitting to the guidance of his instructor, gladly takes up the work suggested to him. In such cases I would cry, Halt! as loudly as any one. But plainly we have here to deal with a fault in the teacher, and this is no evidence of a fault in the subject he teaches. On the contrary, the activity displayed in the field of organic chemistry is positive evidence of the value of the subject: and I may make the same remark concerning what is called modern chemistry in general. Every conception of modern chemistry may be false, and still I claim that these conceptions have been and are still of the highest value for chemistry. There is something in organic chemistry which has furnished enormous incentives for work and which still draws men on, and in this, if nothing else, lies its value. Years ago, in speaking of the Alchemists and their conception of the philosopher's stone, Liebig used these words: "Any idea which stimulates men to work, excites the perceptive faculties, and brings perseverance is a gain for science, for it is work which leads to discoveries. The most lively imagination, the most profound wisdom is not capable of suggesting a thought, which could have acted more powerfully and lastingly upon the minds and powers of man, than did the idea of the philosopher's stone. Without this idea chemistry could not exist to-day in its present perfection."

Anything which stimulates men to work is of value, for it is work which leads to discoveries! These words strike a chord within us, and we feel a thrill acknowledging their truth.

Organic chemistry bids fair to rival Alchemy in the influence which it exerts upon chemists. The number of workers in the field is increasing every day, and the amount of work increases in a corresponding ratio. From this activity good results must be reached. If we are now on the wrong road we shall not discover the fact by sitting down and wondering whether we are or not, but by pushing on with all the energy we can command until we reach some point from which we can learn clearly our position.

The Alchemists had to find out for themselves that they were wrong, but in the process of finding out they established a most valuable lot of facts, they discovered important relations, they furnished the materials from which chemistry as a science was built up. And though we believe now that they were striving for an impossibility, this does not interfere in the least with the value

of their work, or lessen the honor due them for the great results they achieved. It is not probable that all the work done by Alchemists was good work,—in fact it is certain that much of it was very bad, but to this it may be replied that whenever much work is done in any field a considerable proportion of it is sure to be bad. All wheat is accompanied by chaff.

So too in the field of carbon chemistry. It is undoubtedly true that there is much bad work done, but it is also true that much of the work is good. Let us then rather rejoice in the good than complain of the bad. Even bad work is better than none, for, though an error may for a time gain credence, when it is found out the work performed for its overthrow is sure to be more carefully done than if the error had not been propagated. The history of chemistry furnishes abundant examples of the truth of this statement.

Finally, let me repeat what I said distinctly at the beginning of my remarks: "I do not regard organic chemistry as the one important part of chemistry, but only as *an* important part." I have not been arguing the teaching of this branch to the detriment of chemistry in its broadest sense, but merely that chemistry might be presented in its broadest sense, as it surely could not be without a careful study of this part of it. I desire to see the science as a whole presented so that students may rise to higher conceptions concerning it. I would do everything in my power to put a stop to that kind of teaching which emphasizes analysis and loses sight of general principles, which puts chemistry before the student and before the world in the light of an art and not a science. Here let me again quote from my favorite chemical author Liebig. In the year 1840 when the condition of things in Germany as regards chemistry was similar to that at present existing in this country, he said: "In the *Gewerbeinstitut* at Berlin, otherwise so excellent, instruction is given in work requiring skill. Analyses of articles of commerce and the trades or of minerals are the highest that they strive for there; but these are occupations in connection with which judgment and the thinking powers are exercised very little. They are sufficient to make day laborers and machines."

The ordinary laboratory instruction which makes analyses, however complicated these may be, the highest thing to be accomplished, can never make anything of the student but a "day

laborer or a machine." What was written forty years ago, however, will not apply to-day in Germany. In the Gewerbeschule of Berlin, in all the best polytechnic schools chemistry is taught as a science and not as an art, and organic chemistry is included as an essential part of the course. From the polytechnic schools at Berlin, Carlsruhe, Stuttgart, Munich, Zurich, Hanover and Brunswick come many of the most valuable investigations in the field of organic chemistry. Erlenmeyer, Liebermann, Victor Meyer, R. Otto, all known principally through their labors in organic chemistry are professors in polytechnic schools. Baeyer while at the *Gewerbeakademie* in Berlin was also principally engaged in solving the problems of organic chemistry. Has this kind of teaching lowered the character of the work done by technical chemists in Germany? By no means. German chemists are everywhere sought after. We find them in every country where there is use for chemistry, and, as a rule, they are much more efficient than those who have had their training elsewhere. Liebig lived to see the change in his own country and rejoiced in it. May we not hope soon to see a similar change take place in this country? Is not the time near at hand when, by the name chemist, we shall mean one who understands chemistry as it is, and not merely as it was? when the name shall signify something far higher than merely an ability to analyze substances? I truly believe it is; and I believe that the approach of this time will be hastened by encouraging the study of chemistry as a complete science including organic chemistry, in our schools of science, and by stimulating original work in every direction. The signs are propitious. There is more activity in chemical work than there has ever been before among our chemists. It is the duty of every one of us to keep before us high ideals, and to work towards them. Thus may we hope for advancement in its highest sense.

PAPERS READ.

Results of Systematic Analyses of Air, to determine the Cause of the Variations in the Amount of Oxygen therein contained. By Edw. W. Morley,[1] of Hudson, Ohio.

[ABSTRACT.]

Dalton suggested that the lower strata of the air ought to contain a larger proportion of oxygen, on account of its greater specific gravity. This has not been verified by experiment, for up to heights attainable by the ascent of mountains, or by balloons, analyses have been regarded as establishing the uniformity of the composition of the air. There are, however, frequent variations in the proportion of oxygen, amounting even to the fortieth part of the whole oxygen. No probable cause had been suggested for such variations. Some few years ago, Loomis suggested that great and sudden depressions of temperature at the surface of the earth are sometimes caused by the vertical descent of cold air from considerable elevations. Professor Morley connecting this conjecture with that of Dalton, expected to find at time and place of such downfalls of cold air, a less or greater fall in the proportion of oxygen in the air. Such diminution in the proportion of oxygen would be most easily detected at the centre of downfall, but might perhaps exceed the errors of experiment even at places hundreds or a thousand miles from this centre. He had, therefore, made analyses in duplicate of samples of air collected at Hudson, Ohio, during and following considerable falls of the thermometer, from September, 1878, to April, 1879. In every case the result was concordant with his conjecture; the diminution varied from one or two hundreths of one per centum to one half of one per centum in two cases. Such a coincidence could hardly be accidental, and he should follow up the inquiry; for this purpose, he expected to procure the collection of samples at some point in Colorado, a region which Professor Loomis has mentioned as peculiarly liable to downfalls of cold air.

[1]Hurlbut Professor of Chemistry, Western Reserve College.

On Some Details in the Construction of an Apparatus for the Analysis of Gases.[1] By Edw. W. Morley, of Hudson, Ohio.

[ABSTRACT.]

There was described a new form of connection between the eudiometer tube and laboratory tube in an apparatus after the general pattern of Frankland and Ward's modification of Regnault and Reiset's apparatus. This was free from the fragility complained of in the former connection, and worked well. But the chief object of the paper was to show what degree of accuracy in analysis had been attained, so as to afford material for an opinion as to the results mentioned in the preceding paper. One device which had materially increased the accuracy attained was the use of a fine adjustment for the level of the mercury in the eudiometer and pressure tubes. By means of this, a reading could be made, the level of the mercury readjusted in case of slight variations of temperature, and a second reading made, which would be difficult except for this device. The result of a discussion of the sources of error, and of the errors of a series of observations, was, that the probable error of a determination of the proportion of oxygen in the analyses described was a little less than one-hundreth of one per cent.

Preliminary Notice of a Revision of the Atomic Weights. By F. W. Clarke, of Cincinnati, Ohio.

[ABSTRACT.]

The writer, having collected all the published weighings relative to atomic weight determinations, has undertaken their complete recalculation and recombination by the method of least squares. He starts with oxygen, for which the atomic weight has been ascertained by the synthesis of water over copper oxide, and by the relative density of hydrogen and oxygen. In the copper oxide method we have nineteen determinations by Dumas, and

[1] This paper is given in full in the "American Journal of Science" for September, 1879.

eight by Erdmann and Marchand. Dumas' results give a mean of 15·9607, ± ·0071. Erdmann and Marchand's mean is 15·9733, ± ·0113. These means, combined by the usual formula, give a general mean of 15·9642, ± ·006, as the most probable value for the atomic weight of oxygen as ascertained by this method. From the relative density of the two gases, Regnault's figures, the only series worth considering, give us O = 15·9628, ± ·0043. By combining this mean with the other, we get a final general mean of O = 15·9633, ± ·0035. This value is, of course, involved in all the subsequent atomic weight calculations, and its probable error affects all the other probable errors. After oxygen, the elements silver, potassium, sodium, chlorine, bromine, iodine, and sulphur, are discussed in a group. To begin with, all similar data are reduced as far as possible to common standards. For example, there are nine series of determinations of the percentage of oxygen in potassium chlorate. For each series the mean was calculated and its probable error; and the nine means were then combined by the ordinary method into one general mean. Thus all the data relative to the seven elements in question were condensed into twenty ratios; and, from these, eight independent values for the atomic weight of silver could be deduced. In this group of elements data were considered from Berzelius, Penny, Pelouze, Millon, Marignac, Maumené, Gerhardt, Struve, Svanberg and Struve, Turner, Dumas, Cooke, and Stas; each set of experiments receiving exactly the weight indicated by the probable error of its mean. The final results were as follows, putting O = 15·9633, ± ·0035.

Ag, = 107·675, ± ·0096.
Cl, = 35·370, ± ·0145.
Br, = 79·768, ± ·019.
I, = 126·557, ± ·022.
Na, = 22·998, ± ·011.
K, = 39·019, ± ·012.
S, = 31·984, ± ·012.

It is interesting to compare these figures with those obtained by Stas alone. Since the latter took for oxygen the atomic weight of sixteen, the results are comparable only when the new num-

bers are recalculated upon that standard. We then get the following table:

	New values.	Stas.	Difference.
Ag.	107·923.	107·930.	·007.
Cl.	35·451.	35·457.	·006.
Br.	79·951.	79·952.	·001.
I.	126·848.	126·850.	·002.
Na.	23·051.	23·043.	·008.
K.	39·109.	39·137.	·028.
S.	32·058.	32·074.	·016.

These differences, it will be seen, are far within the limits of experimental error; and the table emphasizes in the most forcible way the magnificent accuracy of Stas' work. No other researches than his could stand so severe a test. Professor Clarke hopes soon to complete his discussion for all the elements.

NOTE ON A PECULIAR CASE OF CORROSION OF THE METAL TIN. By J. W. Osborne, of Washington, D. C.

[ABSTRACT.]

THE author stated the well-known fact that the metal tin was not under ordinary circumstances acted upon by water. The piece of tin pipe he exhibited to the subsection showed a remarkable instance of corrosion in which the oxygen of the water in which it was submerged appears to have been the active agent.

This pipe had formed one leg of a large siphon used in the construction of a filter for household purposes.

This filter consisted of a glass bottle holding several gallons, containing a thick layer of wood-charcoal at bottom, and above that, one of well-washed sand; the two layers filling the bottle for two-thirds of its height, about ten inches. The water to be filtered was poured into the upper part of the bottle, which was constantly replenished, and the filtered water was drawn off slowly

when wanted, from a wooden cock which terminated the outside leg of the siphon. This filter had worked well for twenty months, and very large quantities of Potomac water had passed through it. At the end of that time, with the intention of renewing the charcoal, it was taken to pieces. The tin was then found to be deeply pitted, the cavities being filled with tin oxide. This corrosion was limited to the part of the tube corresponding to the position of the charcoal; that portion in contact with the sand, and with the water above the sand was not attacked. The cavities in the tin were clustered irregularly in groups, and the whole surface of the tube at that place was blackened. The inside of the tube was not attacked.

Since these facts were noted, two slips sawn from the same tube and polished were placed upright in earthen-ware vessels. One of these contained a stratum of sand, and the other one of charcoal with sand above it in imitation of the filter. Both were then filled with water, and kept full, and after two weeks both slips were removed, and were now before the section. The slip from the sand alone had come out as it went in, smooth, but slightly tarnished. The other was less tarnished but had brought with it most of the charcoal particles in contact with it (many of them measuring $\frac{1}{20}$ to $\frac{1}{10}$ inches across), and some sand: all adhering very firmly, especially the charcoal. Under the charcoal when it was removed and the surface polished, indications of corrosion were very evident; but the time of exposure was too short to produce the effect with that distinctness which would justify an opinion as to the nature and significance of the action.

In these recent experiments both sand and charcoal were prepared with especial care. The former was treated with acids, and then washed till no trace of acid reaction remained. The latter was freshly ignited, coarsely powdered, and then washed with hot water till all alkaline reaction disappeared.

The analysis of the tin (for which the speaker was indebted to Doctor Antisell of Washington) showed that it contained 94.3 parts Tin, and 5.7 Lead.

On the Sugar content of the sap of the maple tree and the pressure of the same. By H. W. Wiley, of Lafayette, Indiana.

I was unable to find, in the limited literature at my command, any exact statement of the percentage of sugar in the maple sap.

Farmers state generally that 40 gallons of water are required to make one gallon of molasses.

As the maple syrup usually sent into market contains but little over 50 per cent. sugar it would seem that, if the general idea given above be true, there is but little more than 1 per cent. sugar in the sap.

The determinations of sugar were made by the new half-shadow polariscope manufactured by Schmidt & Haensch, Berlin.

The orchard from which the specimens were taken is an old one which has been in use more than fifty years. It is situated two miles west of Lafayette.

My first determinations were made on the 21st of March after two days of a moderately hard freeze.

Specimens of sap were taken from twelve different trees selected so as to represent in size, shape, age, etc., the average growth of the grove.

Following are the percentages of sugar obtained. I also give specimens taken from the same trees four days later, March 25, after two days and nights constant running.

Nos.	Per cent. March 21.	Per cent. March 25.
1	3·95	3·44
2	2·95	2·63
3	3·26	2·80
4	2·70	2·34
5	2·70	2·60
6	3·20	2·42
7	2·51	2·00
8	1·95	1·87
9	3·08	2·00
10	2·67	2·34
11	2·70	2·11
12	3·51	2·74

The twelve trees above given had been "tapped" about a week before the examinations were made.

Wishing to try some perfectly fresh trees, specimens of sap were taken on March 25 from three fresh trees which gave in the polariscope the following numbers.

Nos.	Per cent. sugar.
1	3·93
2	3·75
3	2·42

When I was a boy there was, on my father's farm, a maple tree, which we, in honor of its excellence, had named the sweet tree. The woodpeckers were equally aware of its good properties and every spring, when its "sap was up," would fill it with holes, and the escaping juice drying had colored the bark almost a perfect black. I sent for a specimen of the water from this tree and found the percentage of sugar to be 4.30. This tree, situated nearly two hundred miles south of the grove already mentioned, had just about ended its season when its specimen was taken in the latter part of March. I feel confident that had the specimen been taken in February or early in March it would have shown a percentage of sugar higher by two or three than the one given.

The sugar product is no inconsiderable item in the income of many parts of the western forest land. Among the causes which make it less may be reckoned a mild, irregular winter and long use of the trees. Variations during the season may be referred to the length of time the tree has been "tapped" and the *time* of the season. The sap seems to be richer in sugar early in the season and when the tree is first bored. Subsequent experiments will show if there be any marked annual variation in the amount of sugar.

PRESSURE OF THE SAP.

The mercury gauge of an ordinary Bunser filter-pump was used in these determinations.

The experiments made were at distances of one meter from the ground. My intention was to make an extended series of investigations at different distances from the ground but the abrupt close of the season prevented this from being carried into execution.

A proper opening having been made, the gauge was connected water tight with the tree by drawing a brass tube into the hole, and connecting it by stout rubber hose with the gauge.

The pressure in a number of experiments was,—

minimum = 33.4 c m
maximum = 55.4 " "

CHEMICAL NOTES. By ALBERT R. LEEDS, of Hoboken, N. J.

[ABSTRACT.]

1. SOLUBILITY OF OZONE IN WATER.

IN the first place, the results arrived at by previous experimenters were given; Soret, Meissner, Houzeau and Carius having arrived at the conclusion that ozone is soluble in water, while Schönbein, Marignac, Williamson and Andrews, stated that it was not. Secondly, the methods hitherto employed in the solution of this question were briefly reviewed, from which the importance of employing, in a new trial, tests of a different nature from those previously used, was rendered evident. In the performance of these tests, it was shown that the oxidation of lead plates, completely immersed beneath the surface of water, was much greater after the current of air passing over the surface had been ozonised, than it was before. That under similar circumstances, plumbic sulphide was oxidized to peroxide of lead and free sulphuric acid, and plates of silver foil became tarnished with a film of argentic peroxide. And since the presence of hydrogen peroxide had been carefully excluded, and air or oxygen dissolved in water was incapable of producing these last-mentioned results, they could be attributed only to the solution of the ozone taken up by the water, in which the substances acted upon had been completely immersed.

2. ACTION OF OZONE UPON THE COLOURING MATTER OF PLANTS.

In the annals of the N. Y. Academy of Sciences, Vol. I, No. 7, p. 216, I have given the results obtained when ozonised oxygen

was made to act upon flowers and plants. They were exposed to the action of a slow, continuous current of ozonised oxygen, containing one mgrm. ozone per liter, during intervals varying from eighteen to thirty-six hours. The results, which were mainly negative, were so unsatisfactory, that I have repeated the experiments with the aid of more efficacious apparatus for generating ozone.

One phosphorus ozonator was employed to supply ozone, another, without the phosphorus cakes upon the discs, made a convenient arrangement to contain the flowers. As their stems were placed in vessels filled with water, and the bells were closed by the water contained in the jars, the atmosphere surrounding the flowers was kept moist, which was of importance in conducting the experiments.

I. Bleaching of flowers (152 *liters of air passed over*).

	After 10 *hrs.* (120 *mgrms.*)	*After* 19 *hrs.* (228 *mgrms.*)
HELIOTROPE	Dirty Yellow.	Bleached leaves also.
	(Leaves bleached at ends.)	All perfume destroyed.
BOUVARDIA	Yellow at end of petals.	Partly bleached.
		Leaves white in spots.
VIOLET.....	White in spots.	Some petals white.
PINK.....	Little affected.	Little affected.
PANSY (purple).	White in spots.	Bleached.

At the end, therefore, of 19 hours, when 152 liters of air containing in all 228 mgrms. of ozone had passed over, the bleaching was very imperfect.

II. 1200 *liters of air passed over.* (*Total ozone* 1.8 *grms.*)

	AT THE END OF 5 DAYS.
Lantana, red.	Yellow and somewhat decomposed.
Fuchsia, calyx, carnation-red,	Yellow.
petals, rose-pink.	Dirty White.
Petunia, magenta-coloured.	Calyx and petals partly bleached.
Rose, crimson.	Yellow.
Agapanthus Umbellatus.	White at end of petals.
Verbena, purple with white center.	Bleached.
Pelargonium, scarlet.	"
Euphorbia, salmon-coloured.	Partly bleached.
Fuchsia.	Calyx and stamens yellow.
Verbena, maroon-coloured.	Dirty white.

A piece of calico with a pattern in bright green and black, was completely bleached during the same interval, the green colour having disappeared completely and the stain of the mordant only remaining where the black had been.

III. Ozonised Oxygen. (*Exposure 3½ hours.*)

Rose, light red.	Nearly white, leaves white in spots.
Fuchsia.	Bleached to light red.
Verbena, purple.	White with purple spots.
Verbena, red.	White with red spots.
Petunia, purplish-red.	White in spots.
Pelargonium, pink.	White at end of petals.
Bouvardia.	Dirty white.

No determination was made of the percentage of ozone during this particular experiment. But the same ozoniser was employed as in other trials when it had produced 24 mgrms. ozone per liter. A slow current of the gas was kept flowing during the course of the entire experiment.

Conclusion:— The colouring matters of both leaves and flowers of the species experimented upon were destroyed by ozone. But a considerable percentage of ozone is required to produce this result, or if such small amounts as are obtained in the customary methods of ozonising air by phosphorus are employed (1 to 3 mgrms. per liter), a large volume of ozonised air must be used, and a considerable interval elapse, before bleaching is effected.

3. Bleaching of Sugar Syrups by Ozone.

Not being able to find in chemical journals any accounts of experiments made upon coloured syrups with ozone as a bleaching agent, while there were rumors that such experiments had been tried, although with very partial success, it appeared the easiest way of obtaining satisfactory knowledge upon this point, to make suitable trials in this laboratory.

The material was kindly furnished by Dr. Arno Behr, from syrups manufactured in the refinery of Messrs. Matthiessen & Wiechers, Jersey City. The first specimen was of syrup which had undergone but one filtration, and was of a brownish-yellow colour. In this preliminary experiment, the amount of ozone required to effect the bleaching was not determined. At its close,

the syrup was of a faint straw colour and of slightly acid reaction.

A second trial was made upon a syrup which had been twice filtered, still retaining a strong yellow tint. 20 cc. of the syrup were introduced into a Geissler absorption apparatus, and a slow current of oxygen, ozonised to the extent of 24 mgrm. ozone per liter, passed through it for several hours. When about 100 mgrm. ozone had been brought into contact with the syrup, it had become almost colourless. To our litmus paper it was neutral, although Dr. Behr informs me he detected a very faint reaction.

As determined by Dr. Behr, the filtered syrup, when it came from the refinery, contained in 100 parts, 50 parts of dry substances and 40 parts of pure sugar. The alteration in bleaching is seen in the following table:—

Effect of Ozone upon Filtered Syrup.

Dry substance contains	Unbleached	Bleached
Cane-sugar (by polariscope)	79.7 per cent	80.0 p. c.
Inverted-sugar	12.7 " "	12.7 "

4. Reduction of Carbonic Acid by Phosphorus at Ordinary Temperatures.

As a preliminary determination, rendered essential in the progress of certain studies, it became necessary to ascertain whether phosphorus was entirely without action upon carbonic acid at ordinary temperatures. The inquiry was set on foot with the expectation merely of arriving at a negative result. The experiments were conducted as follows:—

I. The three leaden discs of the phosphorus-ozonator were covered with cakes of fresh phosphorus, and lowered beneath the surface of water in the jars. After the air had been completely expelled by a long continuous current of carbonic acid, the cakes were raised so as to bring them in contact with the gas. As it issued, the gas flowed through a potassium iodide wash-bottle, and then through a Peligot-tube containing strips of paper saturated with solution of palladium chloride. After five hours the iodide was unaffected, but the palladium papers were blackened, and the liquid at the bottom of the U tube contained a notable precipitate. On replacing the papers by fresh ones, they were blackened in the course of fifteen minutes. Allowed to remain over night (sixteen

hours),and aspirated with proper precautions through solution of palladium chloride, the latter showed an increase in weight of forty mgrms.

II. Two wide-mouthed flasks were filled with carbonic acid, great precautions being taken to exclude air. Each contained several sticks of phosphorus partly covered with water. After sealing, one was placed in the dark, the other in sunlight, and both allowed to remain for twenty-four hours. As in the preceding experiments, dense fumes arose in both bottles, those in both the bottles exposed to sunlight being attended with the deposit of much sublimed yellowish-red phosphorus. On testing, the contents of both flasks effected a reduction of the palladium salt.

III. A quantitative determination of the amount of reduction was made in the following manner. A five liter jar was entirely filled with water, the air in the generating apparatus and the various wash-bottles, etc., was removed by a long continued current of carbonic acid, and at last the jar was filled with the gas, the last traces of oxygen having been taken out by the interposition of a wash-bottle containing potassium pyrogallate. After standing for four days in contact with the phosphorus and water at the bottom of the jar, the residual gas was drawn off; first, through a long moist cotton filter, then through a potassium iodide solution, then through three V-tubes, filled respectively with $Ca\,Cl_2$, $Cu_2\,Cl_2$ and $Ca\,Cl_2$, the last acting as a guard. The iodide solution underwent no change, but the acid solution of cuprous chloride had increased in weight 0.150 grm.

IV. In these experiments the increase in weight had been attributed to the reduction of the carbonic acid to carbonic oxide. But on opening the flask above mentioned, the very powerful and characteristic smell of phosphuretted hydrogen was noticed and this led to the following additional trials. A large amount of carefully purified carbonic oxide was passed through a solution of argentic nitrate, with the result of showing that no reduction whatsoever took place in the silver salt. Then a nine liter flask containing thirteen sticks of phosphorus and filled with carbonic acid to the exclusion of every trace of air, was exposed after sealing, to the action of sunlight for four days. The products of the reaction were subsequently aspirated through solutions of KI, $AgNO_3$ and $PdCl_2$. The first and last were unaffected; the silver solution contained a dense black precipitate of argentic

phosphide, of which 0.177 grm. was composed of metallic silver. On attempting to dry this precipitate at 100°, it underwent a gradual decomposition, so that only the actual weight of silver was determined. The largeness of this result shows how considerable an amount of hydrogen phosphide had been formed. But the entire absence of any change in the palladium solutions demonstrates that no carbonic oxide had been produced, and the gas which in the former experiments had been supposed to be carbonic oxide was in fact only hydrogen phosphide. The same reactions were found to occur in diffused light, but the amounts were not so great.

5. Oxidation of Carbonic Oxide by Air over Phosphorus at Ordinary Temperatures.

Having demonstrated by some preliminary experiments that carbonic oxide was converted into acid by air over moist phosphorus at common temperatures, the following experiment was made in order to determine the amount of carbonic acid formed.

A five liter jar, containing five sticks of phosphorus and a little water, was filled with 2500 cc. of carbonic oxide and the remaining space with air. The carbonic oxide was made from potassium ferrocyanide and sulphuric acid, and washed with water, caustic potash and baryta water. On transferring it to the jar it was washed again in a similar manner, a final U-tube filled with baryta-water remaining pellucid, showing the absence of any carbonic acid. The air was purified likewise. At the expiration of eighteen hours, the gases were drawn first through a moist cotton filter, then through a potassium iodide solution, and finally through two baryta waters. The faint rose coloration, which the iodide solution struck with starch water, corresponded to 0.04 mgrm. ozone in the total volume of gas drawn over. The last baryta water remained clear; the first had absorbed fourteen mgrms. carbonic acid. The carbonic acid estimation was made by decomposing the barium salt, and weighing the carbonic acid gas evolved, for fear that some traces of oxides of phosphorus might have escaped the purifiers, and entered into combination with the baryta.

Experiments instituted in order to determine whether *pure* carbonic oxide subjected to the action of moist phosphorus, for long periods and in some instances with the conjoint action of

sunlight, would result in the reduction of the carbon compound to some lower oxide, or to the elementary condition, gave a negative result.

ON THE LIMITS OF METEOROLOGICAL CONDITIONS GOVERNING THE EXTENSION OF BEET-ROOT CULTURE. By WM. MCMURTRIE, of Washington, D. C.

[ABSTRACT.]

IN connection with my duties as Agent and Representative of the Department of Agriculture at the late Paris Exposition, I was directed by the Hon. Commissioner of Agriculture to study the conditions of the culture of the sugar beet and the manufacture of sugar therefrom and the more I studied the cultural branch of the subject and the conditions which govern the extension of the culture into new territory, the more firmly I became convinced that while the social and commercial relations as well as the characters of soil and rotation of crops undoubtedly have a powerful influence, yet the predominant meteorological conditions are the most important of all and this view was strengthened by the observations and remarks made by various authorities and bearing upon the subject. Deherain, commenting upon the results of his work upon the experimental farm attached to the Agricultural school at Grignon, with culture of beets of the same variety and under similar conditions each year, shows that the exceptionally high proportions of sugar found in the roots produced in 1877 are due to the more favorable conditions of rainfall and temperature during the month from September 15 to October 15. This is illustrated in the following table:

YEARS.	AVERAGE TEMPERATURE.	TOTAL RAINFALL. INCHES.	OBSERVATIONS.
1875	58.7° F	2.64	Poor beets
1876	59.4° F	2.17	Poor beets
1877	51.3° F	0.45	Rich beets

Reasoning from the above figures he concludes that the ripening period, which at Grignon is between the dates mentioned, should be dry and cool.

Dr. Joseph Hanaman's observations made at Lobositz concerning the season of 1877 led to similar conclusions. In a paper published on the subject he says: "The temperature and atmospheric conditions were very favorable in 1877 as well for the normal development of the plant as for the production of sugar. Thus the year 1877 may be considered one of the best of the last decennial period. The last months of growth were eminently fitted to facilitate maturation of the roots, the saccharine richness and purity of which were exceptional. The month of September was constantly dry, except toward the last days; the nights were cool."

Briem's observations at Grüssbach were like those already mentioned and lead to similar conclusions. There September was cool and dry, and growth was stopped from that time. He considers that for beet-root culture "the temperature of the soil should be at least 50° F at the time of sowing. A warm month of May favors germination. A hot July makes the roots run to seed: rainy August gives weight: dry September increases the sugar while a wet September has the opposite effect. From May to the middle of June should be warm and tolerably moist with a day temperature of 60° to 65° F. June and July should be relatively cool and rainy with a day temperature of 65° to 67° F. August and September should be tolerably warm and relatively dry with an average temperature of 64.5° to 67.5° F. October cool and fresh with an average temperature of 47.7° F. The sum of degrees of heat [1] required for the production of sugar is divided as follows in round numbers: April 1370°; May 1840°; June 1980°; July 2140°; August 2030°; September 1840°; October 1530°. Total 12730° F in seven months."

In view of these facts I considered that it would be of value to undertake a study and comparison of the average meteorological conditions predominating in the best growing districts of Europe, with a view to the determination if possible of the limits which may govern the extension of the culture into new territory. Finding great difficulty in securing data concerning other conditions on account of the paucity of recorded observations and the limited time at my disposal, I have been forced to content myself princi-

[1] Found by multiplying the monthly average by number of days in the month.

pally with a study of the temperature and rainfall of Austria, Germany, Holland, Belgium and France. For the data required I have had recourse to the publications of Dove, Quétélét, Mascart, Becquerel, Gasparin, and Marié-Davy ; the *Atlas Météorologique de l' Observatoire de Paris*, and the *Annuaire de la Société Météorologique de France.*

It was also my desire to obtain records of the number of rainy days and the relative humidity, but as they are not recorded for all the countries I considered it better for the most part in the present work to omit them. Quétélét has however furnished us with complete records for Belgium and similar records elsewhere give us some notion of the importance of this feature of the subject. I shall return to this point of the number of rainy days later on. My plan of procedure in this work was to collect and tabulate the records of the average of temperature and rainfall for various stations in the countries mentioned and particularly in the beet-growing districts thereof and from the resulting tables determine the limits in question. The second part of the work consisted in plotting on the map by reference to the Smithsonian Temperature and Rain Tables those sections of the United States in which the conditions confined by the limits adopted have been found to predominate. The following abstract from the tables mentioned will serve to show the averages of the conditions in France and Germany.

	LAON.		MONTDIDIER.		LILLE.	CAMBRAI.		FREIBERG.		DRESDEN.		BRESLAU.		HALLE.	
	R. f.	R. ds.	R. f.	R. ds.	Rain Fall.	Temp.	R. f.	Temp.	R. f.	Temp.	R. f.	Temp.	R. f.	Temp.	R. f.
Jan.	2.05	14	1.96	11	2.27	38.75	0.90	27.28	1.58	29.19	1.48	27.34	0.72	26.89	0.84
Feb.	2 10	15	1.41	11	1.69	40.33	0.70	31.67	1.15	33.31	0.63	31.89	0.57	31.32	1.32
Mch.	1.96	18	1.86	12	1.99	44.83	1.18	38.48	1.68	39.92	1.47	38.35	0.74	39.65	0.91
Apr.	1.77	12	1.73	1	1.74	52.70	1.81	43.63	1.68	46.60	1.31	45.93	0.98	47.17	1.33
May	1.77	12	1.60	8	1.43	60.35	1.37	52.61	2.73	58.33	1 75	58.90	1.31	55.69	2.74
June	2.90	13	1.49	12	3.66	68.0	1.77	62.42	2.88	65.17	2.75	61.70	2.12	61.32	3.93
July	2.47	15	2.58	14	3.20	68.23	2.40	65.19	3.61	67.48	3.12	67.75	1.83	66.61	2.66
Aug.	2.62	14	2.48	11	3.74	67.55	1.71	63.55	2.14	65.35	2.29	66.97	1.55	62.85	1.55
Sept.	2.29	14	2.32	11	3.44	62.60	1.71	56.35	2.32	58.26	2.00	59.97	1.30	58.57	1.74
Oct.	2.42	12	2.87	11	2.27	50.90	1.88	48.42	1.85	50.05	1.09	51.10	0.96	48.40	1.20
Nov.	1.90	12	1.73	9	2·55	40.33	1.68	37.67	1.83	38.84	1.48	40.89	0.88	37.55	1.18
Dec.	2.02	13	1.86	12	1.68	38.75	0.83	31.08	1.76	33.69	1.66	31.31	0.88	36.30	5·10

To illustrate the subject more graphically, I have constructed a table of curves showing the average monthly rainfall and temperature for the North of France and Germany and for special stations in the midst of the beet-growing districts of these countries, selecting Cambrai for the first and Halle for the second.[2] These curves show how nearly the general conditions of the beet growing districts of Europe correspond with those stated by Briem to be most favorable to the culture and may even to some extent explain the cause for greater richness of German crops, which is generally referred to the influence of the fiscal system adopted by the Government. They show that the records for the various stations are remarkably regular and similar: the rainfall during the spring months being invariably low, generally below 2 inches: in the summer months higher, generally above 2 and even 3 inches and in the autumn months low or below 2 inches again.

In the study of the records of temperature it appears that the beet-root, within certain limits of course, is more likely in this country to suffer from too high a temperature during the summer months than from a deficiency of heat. Thus it is a rare thing to find, in the meteorological records of the stations within the sections of extended beet-root culture in Europe, a monthly temperature above 70° F, and this fact may I think be considered a significant one, for there is a comparatively small section of the United States where the averages during the summer months will not exceed this figure. Marié-Davy, collecting data with relation to evaporation of moisture from the earth's surface, finds it to be most rapid in the southern latitude as might naturally be expected. But he also finds that the average rainfall, monthly or annual, varies or increases regularly as we go south so that the rainfall at Montpellier or Marseilles is more than double the quantity that falls at Lille. At the same time the evaporation is three times as rapid. Besides this, rains being less frequent and the quantity falling on each occasion greater, much is lost by surface drainage. This will explain why in Southern latitudes of the Northern Hemisphere, notwithstanding the larger quantity of water falling, the beet-root suffers from want of moisture.

In all latitudes it seems that during the growing season frequent rains, even if the quantity falling at each time is small, are an important factor in determining rapid normal development of the

[2] The table of curves is omitted in this abstract.

root and the production of high proportions of sugar. The observations of Quétélet in Belgium, and those of others in France and Germany, show that during the summer months in the beet-growing districts of Europe the number of days upon which rain falls is from 12 to 15 for each month and there are but few recorded instances in which this number for the average falls below 10, while it is frequently found above 15. This condition maintains a constant supply of moisture so favorable to the plant in question.

The second portion of my work consisted in plotting upon the map those sections of the United States in which the records of the meteorological conditions correspond most nearly with those of the beet-growing districts of Europe, thus determining the localities most favorable to the culture in this country. To this end I made use of the Smithsonian Rain and Temperature Tables so admirably compiled by Schott, taking account of only those stations for which the average monthly temperature for June, July, and August is below 70° F, and the average monthly rainfall is above two inches for the same period. All the stations determined by these limits are confined within a band crossing the northern portion of the United States, and its southern boundary is represented by a line passing through southwestern Connecticut, the extreme northern portion of Pennsylvania, closely following the border of the lake in Ohio passing up into southern Michigan and around the lake into the extreme northwest of Indiana and north east of Illinois; in a northerly direction through the middle of Wisconsin, crossing Minnesota at the latitude of St. Paul; thence through northeastern Dakotah and passing into the British Possessions at about the 23d parallel of longitude. The line returns to the United States again in Washington Territory, at about the 44th parallel, and passes in a southerly direction to the northern boundary of California which it crosses at the 45th parallel and then passes to the ocean at a point a little south of the 40th parallel of latitude. There are also isolated stations in the Rocky Mountains, and in some of the southwestern counties of Pennsylvania, but these stations are few, not sufficient for a generalization.

I do not mean to maintain that the sugar beet cannot be produced (and with profit) in any section without the band thus determined, for at one time the culture of the crop and the manu-

facture of sugar were carried on in the Departments of France to the south of Paris and almost as far south as the Cevennes, but it was when the industry was protected by heavy duties upon sugars of foreign production and was free from home tax. But as soon as this protection was withdrawn, the industry was broken up in the Southern Departments and, within two years, more than half the factories of that section were permanently closed, and at present the number of factories located outside the section to the north and east of Paris is but a small proportion of the total number existing in France. It is also an interesting fact that the localities in the United States in which the enterprise of beet-root culture and manufacture of sugar therefrom has been undertaken and has resulted in failure and loss are all without the band determined by the limits under consideration.

In view of the relations pointed out, it would seem eminently advisable that those who may propose the introduction of the culture of the sugar beet in any locality should study closely the meteorological conditions to which it is subject. These are the only influences bearing upon the culture of this important crop which are entirely without the control of human skill and intelligence. Deficiencies in the chemical or physical condition of the soil or in the methods of culture may be modified at the will of the grower, but deficiencies in the meteorological requirements, form, it seems to me, an insuperable obstacle to the permanent extension of this valuable culture.

TITLES OF OTHER PAPERS READ IN SUBSECTION OF CHEMISTRY.

The great Oberstein Industry; method of coloring, cutting and polishing Agates and secondary gems. Illustrated by a fine collection of specimens. By Mrs. Erminnie A. Smith, of Jersey City, N. J.

On the Deterioration of Library Bindings. By Wm. Ripley Nichols, of Boston, Mass.

Observations on the Variations in the temperature and chemical character of the water of Fresh Pond, Mass. By Wm. Ripley Nichols, of Boston, Mass.

On an Accidental Contamination of a Source of Water Supply.* By W. Ripley Nichols, of Boston, Mass.

Exhibition of Crystals of Sapphires from the gem beds of Ceylon, with brief remarks. By A. C. Hamlin, of Bangor, Me.

A Modified Method of collecting and measuring gases soluble in water. By H. W. Wiley, of Lafayette, Ind.

Household Chemistry. By Ellen H. Richards, of Boston, Mass.

On Graphite from the Ducktown Copper Mine. By W. L. Dudley and F. W. Clarke, of Cincinnati, Ohio.

Chemistry of the Saratoga Waters.† By C. F. Chandler, of New York, N. Y.

A Chemical examination of Black Ozokerite. By C. G. Wheeler, of Chicago, Ill.

On the Action of Caustic Alkaline Solution on Glass. By A. A. Breneman, of Ithaca, N. Y.

On the Combustion of Graphite in Analyses of Cast Iron. By A. A. Breneman, of Ithaca, N. Y.

On Colors for Salt-glazed Pottery. By A. A. Breneman, of Ithaca, N. Y.

* Since published in the Eleventh Annual Report of the Mass. State Board of Health, 1880.

† Given as a lecture in General Session, on Monday evening.

SECTION B.

NATURAL HISTORY.

ADDRESS

OF

MAJOR JOHN W. POWELL,

VICE-PRESIDENT, SECTION B.

MYTHOLOGIC PHILOSOPHY.

MEMBERS OF THE ASSOCIATION:—

Ladies and Gentlemen: —

I.—THE GENESIS OF PHILOSOPHY.

THE wonders of the course of nature have ever challenged attention. In savagery, in barbarism, and in civilization alike, the mind of man has sought the explanation of things. The movements of the heavenly bodies, the change of seasons, the succession of night and day, the powers of the air, majestic mountains, ever-flowing rivers, perennial springs, the flight of birds, the gliding of serpents, the growth of trees, the blooming of flowers, the forms of storm-carved rocks, the mysteries of life and death, the institutions of society—many are the things to be explained. The yearning to know is universal. *How* and *why* are everlasting interrogatories profoundly instinct in humanity. In the evolution of the human mind, the instinct of cosmic interrogation follows hard upon the instinct of self-preservation.

In all the operations of nature, man's weal and woe are involved. A cold wave sweeps from the north—rivers and lakes are frozen, forests are buried under snows, and the fierce winds almost congeal the life-fluids of man himself, and indeed man's sources of supply are buried under the rocks of water. At another time the

heavens are as brass, and the clouds come and go with mockery of unfulfilled promises of rain, the fierce midsummer sun pours its beams upon the sands, and blasts heated in the furnace of the desert sear the vegetation; and the fruits, which in more congenial seasons are subsistence and luxury, shrivel before the eyes of famishing men. A river rages and destroys the adjacent valley with its flood. A mountain bursts forth with its rivers of fire, the land is buried and the people are swept away. Lightning shivers a tree and rends a skull. The silent, unseen powers of nature, too, are at work bringing pain or joy, health or sickness, life or death, to mankind. In like manner man's welfare is involved in all the institutions of society. *How* and *why* are the questions asked about all these things—questions springing from the deepest instinct of self-preservation.

In all stages of savage, barbaric, and civilized inquiry every question has found an answer, every *how* has had its *thus*, every *why* its *because*. The sum of the answers to the questions raised by any people constitute its philosophy; hence all peoples have had philosophies consisting of their accepted explanation of things. Such a philosophy must necessarily result from the primary instincts developed in man in the early progress of his differentiation from the beast. This I postulate; if demonstration is necessary, demonstration is at hand. Not only has every people a philosophy, but every stage of culture is characterized by its stage of philosophy. Philosophy has been unfolded with the evolution of the human understanding. The history of philosophy is the history of human opinions from the earlier to the later days—from the lower to the higher culture.

In the production of a philosophy, phenomena must be *discerned*, *discriminated*, *classified*. Discernment, discrimination, and classification are the processes by which a philosophy is developed. In studying the philosophy of a people at any stage of culture, to understand what such a people entertain as the sum of their knowledge it is necessary that we should understand what phenomena they saw, heard, felt, discerned; what discriminations they made, and what resemblances they seized upon as a basis for the classification on which their explanations rested. A philosophy will be higher in the scale, nearer the truth, as the discernment is wider, the discrimination nicer, and the classification better.

The sense of the savage is dull compared with the sense of the

civilized man. There is a myth current in civilization to the effect that the barbarian has highly developed perceptive faculties. It has no more foundation than the myth of the wisdom of the owl. A savage sees but few sights, hears but few sounds, tastes but few flavors, smells but few odors; his whole sensuous life is narrow and blunt, and his facts that are made up of the combination of sensuous impressions are few. In comparison the civilized man has his vision extended away toward the infinitesimal and away toward the infinite; his perception of sound is multiplied to the comprehension of rapturous symphonies; his perception of taste is increased to the enjoyment of delicious viands; his perception of smell is developed to the appreciation of most exquisite perfumes; and his facts that are made up of the combination of sensuous impressions are multiplied beyond enumeration. The stages of discernment from the lowest savage to the highest civilized man constitute a series the end of which is far from the beginning.

If the discernment of the savage is little, his discrimination is less. All his sensuous perceptions are confused; but the confusion of confusion is that universal habit of savagery—the confusion of the objective with the subjective, so that the savage sees, hears, tastes, smells, feels the imaginings of his own mind. Subjectively determined sensuous processes are diseases in civilization, but normal, functional methods in savagery.

The savage philosopher classifies by obvious resemblances—analogic characters. The civilized philosopher classifies by essential affinities — homologic characteristics — and the progress of philosophy is marked by changes from analogic categories to homologic categories.

II.—Two Grand Stages of Philosophy.

There are two grand stages of philosophy—the mythologic and the scientific. In the first, all phenomena are explained by analogies derived from subjective human experiences; in the latter, phenomena are explained as orderly successions of events.

In sublime egotism man first interprets the cosmos as an extension of himself; he classifies the phenomena of the outer world by their analogies with subjective phenomena; his measure of distance is his own pace, his measure of time his own sleep, for he says, "It is a thousand paces to the great rock," or, "It is a hundred sleeps to the great feast." Noises are voices, powers are

hands, movements are made afoot. By subjective examination discovering in himself will and design, and by inductive reason discovering will and design in his fellow men and in animals, he extends the induction to all the cosmos, and there discovers in all things will and design. All phenomena are supposed to be the acts of some one and that some one having will and purpose. In mythologic philosophy the phenomena of the outer physical world are supposed to be the acts of living, willing, designing personages. The simple are compared with and explained by the complex. In scientific philosophy, phenomena are supposed to be children of antecedent phenomena, and so far as science goes with its explanation they are thus interpreted. Man with the subjective phenomena gathered about him is studied from an objective point of view and the phenomena of subjective life are relegated to the categories established in the classification of the phenonema of the outer world; thus the complex is studied by resolving it into its simple constituents.

Some examples of the philosophic methods belonging to widely separated grades of culture may serve to make my statements clearer.

Wind.—The Ute philosopher discerns that men and animals breathe. He recognizes vaguely the phenomena of the wind, and discovers its resemblance to breath, and explains the winds by relegating them to the class of breathings. He declares that there is a monster beast in the north that breathes the winter winds, and another in the south, and another in the east, and another in the west. The facts relating to winds are but partially discerned; the philosopher has not yet discovered that there is an earth-surrounding atmosphere. He fails in making the proper discriminations. His relegation of the winds to the class of breathings is analogic, but not homologic. The basis of his philosophy is personality, and hence he has four wind-gods.

The philosopher of the ancient Northland discovered that he could cool his brow with a fan, or kindle a flame, or sweep away the dust with the wafted air. The winds also cooled his brow, the winds also swept away the dust and kindled the fire into a great conflagration, and when the wind blew he said, "Somebody is fanning the waters of the fiord," or "Somebody is fanning the evergreen forests," and he relegated the winds to the class of fannings, and he said, "The god Hræsvelger, clothed with eagle-

plumes, is spreading his wings for flight, and the winds rise from under them."

The early Greek philosopher discovered that air may be imprisoned in vessels or move in the ventilation of caves, and he recognized wind as something more than breath, something more than fanning, something that can be gathered up and scattered abroad, and so when the winds blew he said, "The sacks have been untied," or "The caves have been opened."

The philosopher of civilization has discovered that breath, the fan-wafted breeze, the air confined in vessels, the air moving in ventilation,—that these are all parts of the great body of air which surrounds the earth, all in motion, swung by the revolving earth, heated at the tropics, cooled at the poles, and thus turned into counter-currents and again deflected by a thousand geographic features, so that the winds sweep down valleys, eddy among mountain-crags, or waft the spray from the crested billows of the sea, all in obedience to cosmic laws. The facts discerned are many, the discriminations made are nice, and the classifications based on true homologies, and we have the science of meteorology, which exhibits an orderly succession of events even in the fickle winds.

Sun and Moon.—The Ute philosopher declares the sun to be a living personage, and explains his passage across the heavens along an appointed way by giving an account of a fierce personal conflict between Ta-vi, the sun-god, and Ta-wats, one of the supreme gods of his mythology.

In that long ago, the time to which all mythology refers, the sun roamed the earth, at will. When he came too near with his fierce heat the people were scorched, and when he hid away in his cave for a long time, too idle to come forth, the night was long and the earth cold. Once upon a time Ta-wats, the hare-god, was sitting with his family by the camp-fire in the solemn woods, anxiously waiting for the return of Ta-vi, the wayward sun-god. Wearied with long watching, the hare-god fell asleep, and the sun-god came so near that he scorched the naked shoulder of Ta-wats. Foreseeing the vengeance which would be thus provoked, he fled back to his cave beneath the earth. Ta-wats awoke in great anger, and speedily determined to go and fight the sun-god. After a long journey of many adventures the hare-god came to the brink of the earth, and there watched long and patiently, till at last the

sun-god coming out he shot an arrow at his face, but the fierce heat consumed the arrow ere it had finished its intended course; then another arrow was sped, but that also was consumed; and another, and still another, till only one remained in his quiver, but this was the magical arrow that had never failed its mark. Ta-wats, holding it in his hand, lifted the barb to his eye and baptized it in a divine tear; then the arrow was sped and struck the sun-god full in the face, and the sun was shivered into a thousand fragments, which fell to the earth, causing a general conflagration. Then Ta-wats, the hare-god, fled before the destruction he had wrought, and as he fled the burning earth consumed his feet, consumed his legs, consumed his body, consumed his hands and his arms—all were consumed but the head alone, which bowled across valleys and over mountains, fleeing destruction from the burning earth until at last, swollen with heat, the eyes of the god burst and the tears gushed forth in a flood which spread over the earth and extinguished the fire. The sun-god was now conquered, and he appeared before a council of the gods to await sentence. In that long council were established the days and the nights, the seasons and the years, with the length thereof, and the sun was condemned to travel across the firmament by the same trail day after day till the end of time.

In this same philosophy we learn that in that ancient time a council of the gods was held to consider the propriety of making a moon, and at last the task was given to Whippoorwill, a god of the night, and a frog yielded himself a willing sacrifice for this purpose, and the Whippoorwill, by incantations, and other magical means, transformed the frog into the new moon. The truth of this origin of the moon is made evident to our very senses; for do we not see the frog riding the moon at night, and the moon is cold, because the frog from which it was made was cold?

The philosopher of Oraibi tells us that when the people ascended by means of the magical tree which constituted the ladder from the lower world to this, they found the firmament, the ceiling of this world, low down upon the earth—the floor of this world. Machito, one of their gods, raised the firmament on his shoulders to where it is now seen. Still the world was dark, as there was no sun, no moon, and no stars. So the people murmured because of the darkness and the cold. Machito said, "Bring me seven maidens," and they brought him seven maidens; and he said, "Bring

me seven baskets of cotton-bolls," and they brought him seven baskets of cotton-bolls; and he taught the seven maidens to weave a magical fabric from the cotton, and when they had finished it he held it aloft, and the breeze carried it away toward the firmament, and in the twinkling of an eye it was transformed into a beautiful full-orbed moon, and the same breeze caught the remnants of flocculent cotton which the maidens had scattered during their work, and carried them aloft, and they were transformed into bright stars. But still it was cold and the people murmured again, and Machito said, "Bring me seven buffalo-robes," and they brought him seven buffalo-robes, and from the densely matted hair of the robes he wove another wonderful fabric, which the storm carried away into the sky, and it was transformed into the full-orbed sun. Then Machito appointed times and seasons, and ways for the heavenly bodies, and the gods of the firmament have obeyed the injunctions of Machito from the day of their creation to the present.

The Norse philosopher tells us that Night and Day, each, has a horse and a car, and they drive successively one after the other around the world in twenty-four hours. Night rides first with her steed named Dew-hair, and every morning as he ends his course he bedews the earth with foam from his bit. The steed driven by Day is Shining-hair. All the sky and earth glisten with the light of his mane. Jarnved, the great iron-wood forest lying to the east of Midgard, is the abode of a race of witches. One monster witch is the mother of many sons in the form of wolves, two of which are Skol and Hate. Skol is the wolf that would devour the maiden Sun, and she daily flies from the maw of the terrible beast, and the moon-man flies from the wolf Hate.

The philosopher of Samos tells us that the earth is surrounded by hollow crystalline spheres set one within another, and all revolving at different rates from east to west about the earth, and that the sun is set in one of these spheres and the moon in another.

The philosopher of civilization tells us that the sun is an incandescent globe, one of the millions afloat in space. About this globe the planets revolve, and the sun and planets and moons were formed from nebulous matter by the gradual segregation of their particles controlled by the laws of gravity, motion and affinity.

The sun, travelling by an appointed way across the heavens with

the never-ending succession of day and night, and the ever-recurring train of seasons, is one of the subjects of every philosophy. Among all peoples, in all times, there is an explanation of these phenomena, but in the lowest stage, way down in savagery, how few the facts discerned, how vague the discriminations made, how superficial the resemblances by which the phenomena are classified! In this stage of culture, all the daily and monthly and yearly phenomena which come as the direct result of the movements of the heavenly bodies are interpreted as the doings of some one—some god acts. In civilization the philosopher presents us the science of astronomy with all its accumulated facts of magnitude, and weights, and orbits, and distances, and velocities— with all the nice discriminations of absolute, relative, and apparent motions; and all these facts he is endeavoring to classify in homologic categories, and the evolutions and revolutions of the heavenly bodies are explained as an orderly succession of events.

Rain.—The Shoshoni philosopher believes the domed firmament to be ice, and surely it is the very color of ice, and he believes further that a monster serpent-god coils his huge back to the firmament and with his scales abrades its face and causes the ice-dust to fall upon the earth. In the winter-time it falls as snow, but in the summer-time it melts and falls as rain, and the Shoshoni philosopher actually sees the serpent of the storm in the rainbow of many colors.

The Oraibi philosopher who lives in a *pueblo* is acquainted with architecture, and so his world is seven-storied. There is a world below and five worlds above this one. Muingwa, the rain-god who lives in the world immediately above, dips his great brush made of feathers of the birds of the heavens into the lakes of the skies and sprinkles the earth with refreshing rain for the irrigation of the crops tilled by these curious Indians who live on the cliffs of Arizona. In winter, Muingwa crushes the ice of the lakes of the heavens and scatters it over the earth, and we have a snow-fall.

The Hindoo philosopher says that the lightning-bearded Indra breaks the vessels that hold the waters of the skies with his thunder-bolts, and the rains descend to irrigate the earth.

The philosopher of civilization expounds to us the methods by which the waters are evaporated from the land and the surface of the sea, and carried away by the winds, and gathered into clouds to be discharged again upon the earth, keeping up for ever that

wonderful circulation of water from the heavens to the earth and from the earth to the heavens—that orderly succession of events in which the waters travel by river, by sea, and by cloud.

Rainbow.—In Shoshoni, the rainbow is a beautiful serpent that abrades the firmament of ice to give us snow and rain. In Norse, the rainbow is the bridge Bifrost spanning the space between heaven and earth. In the Iliad, the rainbow is the goddess Iris, the messenger of the King of Olympus. In Hebrew, the rainbow is the witness to a covenant. In science, the rainbow is an analysis of white light into its constituent colors by the refraction of raindrops.

Falling Stars.—In Ute, falling stars are the excrements of dirty little star-gods. In science—well, I do not know what falling stars are in science. I think they are cinders from the furnace where the worlds are forged. You may call this mythologic or scientific, as you please.

Migration of Birds.—The Algonkian philosopher explains the migration of birds by relating the myth of the combat between Ka-bi-bo-no-ke and Shingapis, the prototype or progenitor of the water-hen, one of their animal gods. A fierce battle raged between Ka-bi-bo-no-ke and Shingapis, but the latter could not be conquered. All the birds were driven from the land but Shingapis; and then was it established that whenever in the future Winter-maker should come with his cold winds, fierce snows, and frozen waters, all the birds should leave for the south except Shingapis and his friends. So the birds that spend their winters north are called by the Algonkian philosophers "the friends of Shingapis."

In contrast to this explanation of the flight of birds may be placed the explanation of the modern evolutionist, who says that the birds migrate in quest of abundance of food and a genial climate, guided by an instinct of migration, which is an accumulation of inherited memories.

Diversity of Languages.—The Kaibabit philosopher accounts for the diversity of languages in this manner: Si-chom-pa Ma-so-its, the grandmother goddess of the sea, brought up mankind from beneath the waves in a sack, which she delivered to the Shi-nau-av brothers, the great wolf-gods of his mythology, and told them to carry it from the shores of the sea to the Kaibab Plateau, and then to open it; but they were by no means to open the package ere their arrival, lest some great disaster should befall. The curi-

osity of the younger Shi-nau-av overcame him, and he untied the sack, and the people swarmed out; but the elder Shi-nau-av, the wiser god, ran back and closed the sack while yet not all the people had escaped, and they carried the sack, with its remaining contents, to the plateau, and there opened it. Those that remained in the sack found a beautiful land—a great plateau covered with mighty forests, through which elk, deer, and antelope roamed in abundance, and many mountain-sheep were found on the bordering crags; *pive*, the nuts of the edible pine, they found on the foot-hills, and *use*, the fruit of the *yucca*, in sunny glades—and *nant* the *meschal* crowns, for their feasts—and *chuar*, the cactus-apple, from which to make their wine; reeds grew about the lakes for their arrow-shafts; the rocks were full of flints for their barbs and knives, and away down in the cañon they found a pipe-stone quarry, and on the hills they found *arraumpive*, their tobacco. Oh, it was a beautiful land that was given to these, the favorites of the gods! The descendants of these people are the present Kaibabits of northern Arizona. Those who escaped by the way, through the wicked curiosity of the younger Shi-nau-av, scattered over the country and became Navajos, Moquis, Sioux, Comanches, Spaniards, Americans—poor, sorry fragments of people without the original language of the gods, and only able to talk in imperfect jargons.

The Hebrew philosopher tells us that on the plains of Shinar the people of the world were gathered to build a city and erect a tower, the summit of which should reach above the waves of any flood Jehovah might send. But their tongues were confused as a punishment for their impiety.

The philosopher of science tells us that mankind was widely scattered over the earth anterior to the development of articulate speech, that the languages of which we are cognizant sprang from innumerable centres as each little tribe developed its own language, and that in the study of any language an orderly succession of events may be discovered in its evolution from a few simple holophrastic locutions to a complex language with a multiplicity of words and an elaborate grammatic structure, by the differentiation of the parts of speech and the integration of the sentence.

A Cough.—A man coughs. In explanation the Ute philosopher would tell us that an *unupits*—a pygmy spirit of evil—had en-

tered the poor man's stomach, and he would charge the invalid with having whistled at night; for in their philosophy it is taught that if a man whistles at night, when the pygmy spirits are abroad, one is sure to go through the open door into the stomach, and the evidence of this disaster is found in the cough which the *unupits* causes. Then the evil spirit must be driven out, and the medicine-man stretches his patient on the ground and scarifies him with the claws of eagles from head to heel, and while performing the scarification a group of men and women stand about, forming a chorus, and medicine-man and chorus perform a fugue in gloomy ululation, for these wicked spirits will depart only by incantations and scarifications.

In our folk-lore philosophy a cough is caused by a "cold," whatever that may be—a vague entity—that must be treated first according to the maxim "Feed a cold and starve a fever," and the "cold" is driven away by potations of bitter teas.

In our medical philosophy a cough may be the result of a clogging of the pores of the skin, and is relieved by clearing those flues that carry away the waste products of vital combustion.

These illustrations are perhaps sufficient to exhibit the principal characteristics of the two methods of philosophy, and, though they cover but narrow fields, it should be remembered that every philosophy deals with the whole cosmos. An explanation of all things is sought—not alone the great movements of the heavens, or the phenomena that startle even the unthinking, but every particular which is observed. Abstractly, the plane of demarcation between the two methods of philosophy can be sharply drawn, but practically we find them strangely mixed; mythologic methods prevail in savagery and barbarism, and scientific methods prevail in civilization. Mythologic philosophies antedate scientific philosophies. The thaumaturgic phases of mythology are the embryonic stages of philosophy, science being the fully developed form. Without mythology there could be no science, as without childhood there could be no manhood, or without embryonic conditions there could be no ultimate forms.

III.—Mythologic Philosophy has Four Stages.

Mythologic philosophy is the subject with which we deal. Its method, as stated in general terms, is this: All phenomena of the outer objective world are interpreted by comparison with those of

the inner subjective world. Whatever happens, some one does it—that some one has a will and works as he wills. The basis of the philosophy is personality. The persons who do the things which we observe in the phenomena of the universe are the gods of mythology—*the cosmos is a pantheon.* Under this system, whatever may be the phenomenon observed, the philosopher asks, "Who does it?" and "Why?" and the answer comes, "A god with his design." The winds blow, and the interrogatory is answered, "Æolus frees them from the cave to speed the ship of a friend, or destroy the vessel of a foe." The actors in mythologic philosophy are gods.

In the character of these gods four stages of philosophy may be discovered. In the lowest and earliest stage everything has life, everything is endowed with personality, will, and design: animals are endowed with all the wonderful attributes of mankind; all inanimate objects are believed to be animate; trees think and speak; stones have loves and hates; hills and mountains, springs and rivers, and all the bright stars, have life—everything discovered objectively by the senses is looked upon subjectively by the philosopher and endowed with all the attributes supposed to be inherent in himself. In this stage of philosophy everything is a god. Let us call it *hecastotheism.*

In the second stage men no longer attribute life indiscriminately to inanimate things; but the same powers and attributes recognized by subjective vision in man are attributed to the animals by which he is surrounded. No line of demarcation is drawn between man and beast; all are great beings endowed with wonderful attributes. Let us call this stage *zoötheism*, when men worship beasts. All the phenomena of nature are the doings of these animal gods, all the facts of nature, all the phenomena of the known universe, all the institutions of humanity known to the philosophers of this stage, are accounted for in the mythologic history of these zoömorphic gods.

In the third stage a wide gulf is placed between man and the lower animals. The animal gods are dethroned, and the powers and phenomena of nature are personified and deified. Let us call this stage *physitheism.* The gods are strictly anthropomorphic, having the form as well as the mental, moral, and social attributes of men. Thus we have a god of the sun, a god of the moon, a god of the air, a god of dawn, and a deity of the night.

In the fourth stage, mental, moral, and social characteristics are personified and deified. Thus we have a god of war, a god of love, a god of revelry, a god of plenty, and like personages who preside over the institutions and occupations of mankind. Let us call this *psychotheism*. With the mental, moral, and social characteristics in these gods are associated the powers of nature; and they differ from nature-gods chiefly in that they have more distinct psychic characteristics.

Psychotheism, by the processes of mental integration, develops in one direction into monotheism, and in the other into pantheism. When the powers of nature are held predominant in the minds of the philosophers through whose cogitations this evolution of theism is carried on, pantheism, as the highest form of psychotheism, is the final result; but when the moral qualities are held in highest regard in the minds of the men in whom this process of evolution is carried on, *monotheism*, or a god whose essential characteristics are moral qualities, is the final product. The monotheistic god is not nature, but presides over and operates through nature. Psychotheism has long been recognized. All of the earlier literature of mankind treats largely of these gods, for it is an interesting fact that in the history of any civilized people, the evolution of psychotheism is approximately synchronous with the invention of an alphabet. In the earliest writings of the Egyptians, the Hindoos, and the Greeks, this stage is discovered, and Osiris, Indra, and Zeus are characteristic representatives. As psychotheism and written language appear together in the evolution of culture, this stage of theism is consciously or unconsciously a part of the theme of all written history.

The paleontologist, in studying the rocks of the hill and the cliffs of the mountain, discovers, in inanimate stones, the life-forms of the ancient earth. The geologist, in the study of the structure of valleys and mountains, discovers groups of facts that lead him to a knowledge of more ancient mountains and valleys and seas, of geographic features long ago buried, and followed by a new land with new mountains and valleys, and new seas. The philologist, in studying the earliest writings of a people, not only discovers the thoughts purposely recorded in those writings, but is able to go back in the history of the people many generations, and discover with even greater certainty the thoughts of the more ancient people who made the words. Thus the writings of the

Greeks, the Hindoos, and the Egyptians, that give an account of their psychic gods, also contain a description of an earlier theism unconsciously recorded by the writers themselves. Psychotheism prevailed when the sentences were coined, physitheism when the words were coined. So the philologist discovers physitheism in all ancient literature. But the verity of that stage of philosophy does not rest alone upon the evidence derived from the study of fossil philosophies through the science of philology. In the folk-lore of every civilized people having a psychotheic philosophy, an earlier philosophy with nature-gods is discovered.

The different stages of philosophy which I have attempted to characterize have never been found in purity. We always observe different methods of explanation existing side by side, and the type of a philosophy is determined by the prevailing characteristics of its explanation of phenomena. Fragments of the earlier are always found side by side with the greater body of the later philosophy. Man has never clothed himself in new garments of wisdom, but has ever been patching the old, and the old and the new are blended in the same pattern, and thus we have atavism in philosophy. So in the study of any philosophy which has reached the psychotheic age, patches of the earlier philosophy are always seen. Ancient nature-gods are found to be living and associating with the supreme psychic deities. Thus in anthropologic science there are three ways by which to go back in the history of any civilized people and learn of its barbaric physitheism. But of the verity of this stage we have further evidence. When Christianity was carried north from central Europe, the champions of the new philosophy, and its consequent religion, discovered, among those who dwelt by the glaciers of the north, a barbaric philosophy which they have preserved to history in the Eddas and Sagas, and Norse literature is full of a philosophy in a transition state, from physitheism to psychotheism; and, mark! the people discovered in this transition state were inventing an alphabet—they were carving Runes. Then a pure physitheism was discovered in the Aztec barbarism of Mexico, and elsewhere on the globe many people were found in that stage of culture to which this philosophy properly belongs. Thus the existence of physitheism as a stage of philosophy is abundantly attested. Comparative mythologists are agreed in recognizing these two stages. They might not agree to throw all of the higher and

later philosophies into one group, as I have done, but all recognize the plane of demarcation between the higher and the lower groups as I have drawn it. Scholars, too, have come essentially to an agreement that physitheism is earlier and older than psychotheism. Perhaps there may be left a "doubting Thomas" who believes that the highest stage of psychotheism—that is, monotheism—was the original basis for the philosophy of the world, and that all other forms are degeneracies from that primitive and perfect state. If there be such a man left, to him what I have to say about philosophy is blasphemy.

Again, all students of comparative philosophy, or comparative mythology, or comparative religion, as you may please to approach this subject from different points of view, recognize that there is something else; that there are philosophies, or mythologies, or religions, not included in the two great groups. All that something else has been vaguely called *fetichism*. I have divided it into two parts, *hecastotheism* and *zoötheism*. The verity of zoötheism as a stage of philosophy rests on abundant evidence. In psychotheism it appears as *devilism* in obedience to a well-known law of comparative theology, viz., that the gods of a lower and superseded stage of culture oftentimes become the devils of a higher stage. So in the very highest stages of psychotheism we find beast-devils. In Norse mythology, we have Fenris the wolf, and Jormungandur the serpent. Dragons appear in Greek mythology, the bull is an Egyptian god, a serpent is found in the Zendavesta; and was there not a scaly fellow in the garden of Eden? So common are these beast-demons in the higher mythologies that they are used in every literature as rhetorical figures. So we find, as a figure of speech, the great red dragon with seven heads and ten horns, with tail that with one brush sweeps away a third of the stars of heaven. And wherever we find nature-worship we find it accompanied with beast-worship. In the study of higher philosophies, having learned that lower philosophies often exist side by side with them, we might legitimately conclude that a philosophy based upon animal gods had existed previous to the development of physitheism; and philologic research leads to the same conclusion. But we are not left to base this conclusion upon an induction only, for in the examination of savage philosophies we actually discover zoötheism in all its proportions. Many of the Indians of North America, and many of South

America, and many of the tribes of Africa, are found to be zoötheists. Their supreme gods are animals—tigers, bears, wolves, serpents, birds. Having discovered this, with a vast accumulation of evidence, we are enabled to carry philosophy back one stage beyond physitheism, and we can confidently assert that all the philosophies of civilization have come up through these three stages.

And yet, there are fragments of philosophy discovered which are not zoötheistic, physitheistic, nor psychotheistic. What are they? We find running through all three stages of higher philosophy that phenomena are sometimes explained by regarding them as the acts of persons who do not belong to any of the classes of gods found in the higher stages. We find fragments of philosophy everywhere which seem to assume that all inanimate nature is animate: that mountains and hills, and rivers and springs, that trees and grasses, that stones, and all fragments of things are endowed with life and with will, and act for a purpose. These fragments of philosophy lead to the discovery of hecastotheism. Philology also leads us back to that state when the animate and the inanimate were confounded, for the holophrastic roots into which words are finally resolved show us that all inanimate things were represented in language as actors. Such is the evidence on which we predicate the existence of hecastotheism as a veritable stage of philosophy. Unlike the three higher stages, it has no people extant on the face of the globe, known to be in this stage of culture. The philosophies of many of the lowest tribes of mankind are yet unknown, and hecastotheism may be discovered; but at the present time we are not warranted in saying that any tribe entertains this philosophy as its highest wisdom.

IV. Outgrowths from Mythologic Philosophy.

The three stages of mythologic philosophy that are still extant in the world must be more thoroughly characterized, and the course of their evolution indicated. But in order to do this clearly, certain outgrowths from mythologic philosophy must be explained, certain theories and practices that necessarily result from this philosophy, and that are intricately woven into the institutions of mankind.

Ancientism.—The first I denominate ancientism. Yesterday

was better than to-day. The ancients were wiser than we. This belief in a better day and a better people in the elder time is almost universal among mankind. A belief so widely spread, so profoundly entertained, must have for its origin some important facts in the constitution or history of mankind. Let us see what they are.

In the history of every individual, the sports and joys of childhood are compared and contrasted with the toils and pains of old age. Greatly protracted life, in savagery and barbarism, is not a boon to be craved. In that stage of society where the days and the years go by with little or no provision for a time other than that which is passing, the old must go down to the grave through poverty and suffering. In that stage of culture to-morrow's bread is not certain, and to-day's bread is often scarce. In civilization, plenty and poverty live side by side; the palace and the hovel are on the same landscape; the rich and poor elbow each other on the same street: but, in savagery, plenty and poverty come with recurring days to the same man, and the tribe is rich to-day and poor to-morrow, and the days of want come in every man's history; and when they come the old suffer most, and the burden of old age is oppressive. In youth, activity is joy; in old age, activity is pain. No wonder, then, that old age loves youth, or that to-day loves yesterday, for the instinct is born of the inherited experiences of mankind.

But there is yet another and more potent reason for ancientism. That tale is the most wonderful that has been most repeated, for the breath of speech is the fertilizer of story. Hence, the older the story, the greater its thaumaturgics. Thus, yesterday is greater than to-day by natural processes of human exaggeration. Again, that is held to be most certain, and hence most sacred, which has been most often affirmed. A Brahman was carrying a goat to the altar. Three thieves would steal it. So they placed themselves at intervals along the way by which the pious Brahman would travel. When the venerable man came to the first thief he was accosted: "Brahman, why do you carry a dog?" Now, a dog is an unclean beast which no Brahman must touch. And the Brahman, after looking at his goat, said: "You do err; this is a goat." And when the old man reached the second thief, again he was accosted: "Brahman, why do you carry a dog?" So the Brahman put his goat on the ground, and after narrowly scrutiniz-

ing it, he said, "Surely this is a goat," and went on his way. When he came to the third thief he was once more accosted: "Brahman, why do you carry a dog?" Then the Brahman having thrice heard that his goat was a dog, was convinced, and throwing it down, he fled to the temple for ablution, and the thieves had a feast.

The child learns not for himself, but is taught, and accepts as true that which is told, and a propensity to believe the affirmed is implanted in his mind. In every society some are wise and some are foolish, and the wise are revered, and their affirmations are accepted. Thus, the few lead the multitude in knowledge, and the propensity to believe the affirmed started in childhood is increased in manhood in the great average of persons constituting society, and these propensities are inherited from generation to generation, until we have a cumulation of effects.

The propagation of opinions by affirmation, the cultivation of the propensity to believe that which has been affirmed many times, let us call *affirmatization*. If the world's opinions were governed only by the principles of mythologic philosophy, affirmatization would become so powerful that nothing would be believed but the anciently affirmed. Men would come to no new knowledge. Society would stand still listening to the wisdom of the fathers. But the power of affirmatization is steadily undermined by science.

And, still again, the institutions of society conform to its philosophy. The explanation of things always includes the origin of human institutions. So the welfare of society is based on philosophy, and the venerable sayings which constitute philosophy are thus held as sacred. So ancientism is developed from accumulated life-experiences; by the growth of story in repeated narration; by the steadily increasing power of affirmatization, and by respect for the authority upon which the institutions of society are based; all accumulating as they come down the generations. That we do thus inherit effects we know, for has it not been affirmed in the Book that "the fathers have eaten grapes, and the children's teeth are set on edge"? As men come to believe that the "long ago" was better than the "now," and the dead were better than the living, then philosophy must necessarily include a theory of degeneracy, which is a part of ancientism.

Theistic Society.—Again, the actors in mythologic philosophy are personages, and we always find them organized in societies.

The social organization of mythology is always found to be essentially identical with the social organization of the people who entertain the philosophy. The gods are husbands and wives, and parents and children, and the gods have an organized government. This gives us theistic society, and we can not properly characterize a theism without taking its mythic society into consideration.

Spiritism.—In the earliest stages of society of which we have practical knowledge by acquaintance with the people themselves, a belief in the existence of spirits prevails — a shade, an immaterial existence, which is the duplicate of the material personage. The genesis of this belief is complex. The workings of the human mind during periods of unconsciousness lead to opinions that are enforced by many physical phenomena.

First, we have the activities of the mind during sleep, when the man seems to go out from himself, to converse with his friends, to witness strange scenes, and to have many wonderful experiences. Thus the man seems to have lived an eventful life, when his body was, in fact, quiescent and unconscious. Memories of scenes and activities in former days, and the inherited memories of scenes witnessed and actions performed by ancestors, are blended in strange confusion by broken and inverted sequences. Now and then the dream-scenes are enacted in real life, and the infrequent coincidence or apparent verification makes deep impression on the mind, while unfulfilled dreams are forgotten. Thus the dreams of sleepers are attributed to their immaterial duplicates — their spirits. In many diseases, also, the mind seems to wander, to see sights, and to hear sounds, and to have many wonderful experiences, while the body itself is apparently unconscious. Sometimes on restored health, the person may recall these wonderful experiences, and during their occurrence the subject talks to unseen persons, and seems to have replies and to act, to those who witness, in such a manner that a second self—a spirit independent of the body—is suggested. When disease amounts to long-continued insanity, all of these effects are greatly exaggerated, and make a deep impression upon all who witness the phenomena. Thus the hallucinations of fever-racked brains, and mad minds, are attributed to spirits.

The same conditions of apparent severance of mind and body witnessed in dreams and hallucinations are often produced artificially in the practice of *ecstasism*. In the vicissitudes of savage

life, while little or no provision is made for the future, there are times when the savage resorts to almost anything at hand as a means of subsistence, and thus all plants and all parts of plants, seed, fruit, flowers, leaves, bark, roots—anything in times of extreme want—may be used as food. But experience soon teaches the various effects upon the human system which are produced by the several vegetable substances with which he meets, and thus the effect of narcotics is early discovered, and the savage in the practice of his religion oftentimes resorts to these native drugs for the purpose of producing an ecstatic state under which divination may be performed. The practice of ecstasism is universal in the lower stages of culture. In times of great anxiety, every savage and barbarian seeks to know of the future. Through all the earlier generations of mankind, ecstasism has been practised, and civilized man has thus an inherited appetite for narcotics to which the enormous propensity to drunkenness existing in all nations bears witness. When the great actor in his personation of Rip Van Winkle holds his goblet aloft and says, "Here's to your health and to your family's and may they live long and prosper," he connects the act of drinking with a prayer, and unconsciously demonstrates the origin of the use of stimulants. It may be that when the jolly companion has become a loathsome sot, and his mind is ablaze with the fire of drink, and he sees uncouth beasts in horrid presence, that inherited memories haunt him with visions of the beast-gods worshipped by his ancestors at the very time when the appetite for stimulants was created. But ecstasism is produced in other ways, and for this purpose the savage and barbarian often resorts to fasting and bodily torture. In many ways he produces the wonderful state, and the visions of ecstasy are interpreted as the evidence of spirits,

Many physical phenomena serve to confirm this opinion. It is very late in philosophy when shadows are referred to the interception of the rays of the sun. In savagery and barbarism, shadows are supposed to be emanations from or duplicates of the bodies causing the shadows. And what savage understands the reflection of the rays of the sun by which images are produced? They also are supposed to be emanations or duplications of the object reflected. No savage or barbarian could understand that the waves of the air are turned back and sound is duplicated in an echo. He knows not that there is an atmosphere, and to him

the echo is the voice of an unseen personage—a spirit. There is no theory more profoundly implanted in early mankind than that of spiritism.

Thaumaturgics.—The gods of mythologic philosophies are created to account for the wonders of nature. Necessarily they are a wonder-working folk, and having been endowed with these magical powers in all the histories given in mythic tales of their doings on the earth, we find them performing most wonderful feats. They can transform themselves; they can disappear and reappear; all their senses are magical; some are endowed with a multiplicity of eyes, others have a multiplicity of ears; in Norse mythology the watchman on the rainbow bridge could hear the grass grow and wool on the backs of sheep; arms can stretch out to grasp the distance, tails can coil about mountains, and all powers become magical. But the most wonderful power with which the gods are endowed is the power of will, for we find that they can think their arrows to the hearts of their enemies; mountains are overthrown by thought, and thoughts are projected into other minds. Such are the thaumaturgics of mythologic philosophy.

Mythic Tales.—Early man having created through the development of his philosophy a host of personages, these gods must have a history. A part of that history, and the most important part to us as students of philosophy, is created in the very act of creating the gods themselves. I mean that portion of their history which relates to the operations of nature, for the gods were created to account for those things. But to this is added much else of adventure. The gods love as men love, and go in quest of mates. The gods hate as men hate, and fight in single combat or engage in mythic battles; and the history of these adventures impelled by love and hate, and all other passions and purposes with which men are endowed, all wovén into a complex tissue with their doings in carrying out the operations of nature, constitutes the web and woof of mythology.

Religion.—Again, as human welfare is deeply involved in the operations of nature, man's chief interest is in the gods. In this interest religion originates. Man, impelled by his own volition, guided by his own purposes, aspires to a greater happiness, and endeavor follows endeavor, but at every step his progress is impeded; his own powers fail before the greater powers of nature;

his powers are pygmies, nature's powers are giants, and to him these giants are gods with wills and purposes of their own, and he sees that man in his weakness can succeed only by allying himself with the gods. Hence, impelled by this philosophy, man must have communion with the gods, and in this communion he must influence them to work for himself. Hence, religion, which has to do with the relations which exist between the gods and man, is the legitimate offspring of mythologic philosophy.

Thus we see that out of mythologic philosophy, as branches of the great tree itself, there grow ancientism, theistic society, spiritism, thaumaturgics, mythic tales, and religion.

V. The Evolution of Mythologic Philosophy.

I shall now give a summary characterization of zoötheism, then call attention to some of the relics of hecastotheism found therein, and proceed with a brief statement of the higher stages of theism. The apparent and easily accessible is studied first. In botany, the trees and the conspicuous flowering plants of garden, field, and plain were first known, and then all other plants were vaguely grouped as weeds: but, since the most conspicuous phenogamous plants were first studied, what vast numbers of new orders, new genera, and new species have been discovered, in the progress of research, to the lowest cryptogams!

In the study of ethnology, we first recognized the more civilized races. The Aryan, Hamites, Shemites, and Chinese, and the rest were the weeds of humanity—the barbarian and savage, sometimes called Turanians. But, when we come carefully to study these lower people, what numbers of races are discovered! In North America alone we have more than seventy-five—seventy-five stocks of people speaking seventy-five stocks of language, and some single stocks embracing many distinct languages and dialects. The languages of the Algonkian family are as diverse as the Indo-European tongues. So are the languages of the Dakotans, the Shoshonians the Tinnéans, and others: so that in North America we have more than five hundred languages spoken to-day. Each linguistic stock is found to have a philosophy of its own, and each stock as many branches of philosophy as it has languages and dialects. North America presents a magnificent field for the study of savage and barbaric philosophies.

This vast region of thought has been explored only by a few

adventurous travellers in the world of science. No thorough survey of any part has been made. Yet the general outlines of North American philosophy are known, but the exact positions, the details, are all yet to be filled in—as the geography of the general outline of North America is known by exploration, but the exact positions and details of topography are yet to be filled in as the result of careful survey. Myths of the Algonkian stock are found in many a volume of *Americana*, the best of which were recorded by the early missionaries who came from Europe, though we find some of them, mixed with turbid speculations, in the writings of Schoolcraft. Many of the myths of the Indians of the South, in that region stretching back from the great Gulf, are known—some collected by travellers, others by educated Indians.

Many of the myths of the Iroquois are known. The best of these are in the writings of Morgan, America's greatest anthropologist. Missionaries, travellers, and linguists have given us a great store of the myths of the Dakotan stock. Many myths of the Tinnéan also have been collected. Petitot has recorded a number of those found at the North, and we have in manuscript some of the myths of a southern branch—the Navajos. Perhaps the myths of the Shoshonians have been collected more thoroughly than those of any other stock. These are yet unpublished. Powers has recorded many of the myths of various stocks in California, and the old Spanish writings give us a fair collection of the Nahuatlan myths of Mexico, and Rink has presented an interesting volume on the mythology of the Innuits; and, finally, fragments of mythology have been collected from nearly all the tribes of North America, and they are scattered through thousands of volumes, so that the literature is vast. The brief description which I shall give of zoötheism is founded on a study of the materials which I have thus indicated.

All these tribes are found in the higher stages of savagery, or the lower stages of barbarism, and their mythologies are found to be zoötheistic among the lowest, physitheistic among the highest, and a great number of tribes are found in a transition state, for zoötheism is found to be a characteristic of savagery, and physitheism of barbarism, using the terms as they have been defined by Morgan. The supreme gods of this stage are animals. The savage is intimately associated with animals. "From them he obtains the larger part of his clothing, and much of his food,

and he carefully studies their habits and finds many wonderful things. Their knowledge and skill and power appear to him to be superior to his own. He sees the mountain-sheep fleet among the crags, the eagle soaring in the heavens, the humming-bird poised over its blossom-cup of nectar, the serpents swift without legs, the salmon scaling the rapids, the spider weaving its gossamer web, the ant building a play-house mountain—in all animal nature he sees things too wonderful for him, and from admiration he grows to adoration, and the animals become his gods."[1]

Ancientism plays an important part in this zoötheism. It is not the animals of to-day whom the Indians worship, but their progenitors—their prototypes. The wolf of to-day is a howling pest, but that wolf's ancestor—the first of the line—was a god. The individuals of every species are supposed to have descended from an ancient being—a progenitor of the race; and so they have a grizzly-bear-god, an eagle-god, a rattlesnake-god, a trout-god, a spider-god—a god for every species and variety of animal.

By these animal-gods all things were established. The heavenly bodies were created and their ways appointed, and when the powers and phenomena of nature are personified the personages are beasts, and all human institutions also were established by the ancient animal-gods.

The ancient animals of any philosophy of this stage are found to constitute a clan or *gens*—a body of relatives, or *consanguinii*, with grandfathers, fathers, sons, and brothers. In Ute theism, the ancient Togoav, the first rattle-snake, is the grandfather, and all the animal-gods are assigned to their relationships. Grandfather Togoav, the wise, was the chief of the council, but Shinauav, the ancient wolf, was the chief of the clan.

There were many other clans and tribes of ancient gods with whom these supreme gods had dealings, of which hereafter; and, finally, each of these ancient gods became the progenitor of a new tribe, so that we have a tribe of bears, a tribe of eagles, a tribe of rattlesnakes, a tribe of spiders, and many other tribes, as we have tribes of Utes, tribes of Sioux, tribes of Navajos: and in that philosophy tribes of animals are considered to be coördinate

[1] *Vidé* "Outlines of the Philosophy of the North American Indians," by J. W. Powell. Read before the American Geographical Society at Chickering Hall, December 29, 1876.

with tribes of men. All of these gods have invisible duplicates—spirits—and they have often visited the earth. All of the wonderful things seen in nature are done by the animal-gods. That elder life was a magic life; but the descendants of the gods are degenerate. Now and then as a medicine-man by practising sorcery can perform great feats, so now and then there is a medicine-bear, a medicine-wolf, or a medicine-snake that can work magic.

On winter nights the Indians gather about the camp-fire and then the doings of the gods are recounted in many a mythic tale. I have heard the venerable and impassioned orator on the camp-meeting stand rehearse the story of the crucifixion, and have seen the thousands gathered there weep in contemplation of the story of divine suffering, and heard their shouts roll down the forest aisles as they gave vent to their joy at the contemplation of redemption. But the scene was not a whit more dramatic than another I have witnessed in an evergreen forest of the Rocky Mountain region, where a tribe was gathered under the great pines, and the temple of light from the blazing fire was walled by the darkness of midnight, and in the midst of the temple stood the wise old man telling in simple savage language the story of Tawats, when he conquered the sun and established the seasons and the days. In that pre-Columbian time, before the advent of white men, all the Indian tribes of North America gathered on winter nights by the shores of the seas where the tides beat in solemn rhythm, by the shores of the great lakes where the waves dashed against frozen beaches, and by the banks of the rivers flowing ever in solemn mystery—each in its own temple of illumined space—and listened to the story of its own supreme gods, the ancients of time.

Religion, in this stage of theism, is sorcery. Incantation, dancing, fasting, bodily torture, and ecstasism are practised. Every tribe has its potion or vegetable drug, by which the ecstatic state is produced, and their venerable medicine-men see visions and dream dreams. No enterprise is undertaken without consulting the gods, and no evil impends but they seek to propitiate the gods. All daily life, to the minutest particular, is religious. This stage of religion is characterized by fetichism. Every Indian is provided with his charm or fetich, revealed to him in some awful hour of ecstasy produced by fasting, or feast-

ing, or drunkenness, and that fetich he carries with him to bring good luck, in love or in combat, in the hunt or on the journey. He carries a fetich suspended to his neck, he ties a fetich to his bow, he buries a fetich under his tent, he places a fetich under his pillow of wild-cat skins, he prays to his fetich, he praises it, or chides it; if successful, his fetich receives the glory; if he fail, his fetich is disgraced. These fetiches may be fragments of bone or shell, the tips of the tails of animals, the claws of birds or beasts, perhaps dried hearts of little warblers, shards of beetles, leaves powdered and held in bags, or crystals from the rocks —anything curious may become a fetich. Fetichism, then, is a religious means, not a philosophic or mythologic state. Such are the supreme gods of the savage, and such the institutions which belong to their theism. But they have many other inferior gods. Mountains, hills, valleys, and great rocks have their own special deities—invisible spirits—and lakes, rivers, and springs are the homes of spirits. But all these have animal forms when in proper *personæ*. Yet some of the medicine-spirits can transform themselves, and work magic as do medicine-men. The heavenly bodies are either created personages or ancient men or animals translated to the sky. And, last, we find that ancestors are worshipped as gods.

Among all the tribes of North America with which we are acquainted tutelarism prevails. Every tribe and every clan has its own protecting god, and every individual has his "my god." It is a curious fact that every Indian seeks to conceal the knowledge of his "my god" from all other persons, for he fears that, if his enemy should know of his tutelar deity, he might by extraordinary magic succeed in estranging him, and be able to compass his destruction through his own god.

In this summary characterization of zoötheism, I have necessarily systematized my statements. This, of course, could not be done by the savage himself. He could give you its particulars, but could not group those particulars in any logical way. He does not recognize any system, but talks indiscriminately, now of one, now of another god, and with him the whole theory as a system is vague and shadowy, but its particulars are vividly before his mind and the certainty with which he entertains his opinions leaves no room to doubt his sincerity.

But there is yet another phase of theism discovered. Some-

times a particular mountain, or hill, or some great rock, some waterfall, some lake, or some spring receives special worship, and is itself believed to be a deity. This seems to be a relic of hecastotheism. Fetichism, also, seems to have come from that lower grade, and all the minor deities, the spirits of mountains and hills and forests, seem to have been derived from that same stage, but with this development, that the things themselves are not worshipped, but their essential spirits.

From zoötheism, as described, to physitheism the way is long. Gradually, in the progress of philosophy, animal-gods are dethroned and become inferior gods or are forgotten; and gradually the gods of the firmament—the sun, the moon, the stars—are advanced to supremacy; the clouds, the storms, the winds, day and night, dawn and gloaming, the sky, the earth, the sea, and all the various phases of nature perceived by the barbaric mind, are personified and deified and exalted to a supremacy coördinate with the firmament gods; and all the gods of the lower stage that remain—animals, demons, and all men—belong to inferior tribes. The gods of the sky—the shining ones, those that soar on bright wings, those that are clothed in gorgeous colors, those that came from we know not where, those that vanish to the unknown—are the supreme gods. We always find these gods organized in great tribes, with mighty chieftains who fight in great combats or lead their hosts in battle, and return with much booty. Such is the theism of ancient Mexico, such the theism of the Northland, and such the theism discovered among the ancient Aryans.

From this stage to psychotheism the way is long, for evolution is slow. Gradually men come to differentiate more carefully between good and evil, and the ethic character of their gods becomes the subject of consideration, and the good gods grow in virtue, and the bad gods grow in vice. Their identity with physical objects and phenomena is gradually lost. The different phases or conditions of the same object or phenomenon are severed, and each is personified. The bad gods are banished to underground homes, or live in concealment, from which they issue on their expeditions of evil. Still, all powers exist in these gods, and all things were established by them. With the growth of their moral qualities no physical powers are lost, and the spirits of the physical bodies and phenomena become demons, subordinate to the great gods who preside over nature and human institutions.

We find, also, that these superior gods are organized in societies. I have said the Norse mythology was in a transition state from physitheism to psychotheism. The Asas, or gods, lived in Asgard, a mythic communal village, with its Thing or Council, the very counterpart of the communal village of Iceland. Olympus was a Greek city.

Still further in the study of mythologic philosophy we see that more and more supremacy falls into the hands of the few, until monotheism is established on the plan of the empire. Then all of the inferior deities whose characters are pure become ministering angels, and the inferior deities whose characters are evil become devils, and the differentiation of good and evil is perfected in the gulf between heaven and hell. In all this time from zoötheism to monotheism, ancientism becomes more ancient, and the times and dynasties are multiplied. Spiritism is more clearly defined, and spirits become eternal; mythologic tales are codified, and sacred books are written; divination for the result of amorous intrigue has become the prophecy of immortality, and thaumaturgics is formulated as the omnipresent, the omnipotent, the omniscient — the infinite.

Time has failed me to tell of the evolution of idolatry from fetichism, priestcraft from sorcery, and of their overthrow by the doctrines that were uttered by that voice on the Mount. Religion, that was fetichism and ecstasism and sorcery, is now the yearning for something better, something purer, and the means by which this highest state for humanity may be reached, the ideal worship of the highest monotheism, is "in spirit and in truth." The steps are long from Shinauav, the ancient of wolves, by Zeus, the ancient of skies, to Jehovah, the "ancient of days."

When society shall have passed to complete integration in the unification of the nations, and differentiation is perfected in universal liberty, then the sole philosophy will be science.

PAPERS READ.

The History of some pre-Cambrian Rocks in America and Europe. By T. Sterry Hunt, of Montreal, Canada.

I. Introduction.

One of the earliest distinctions in modern geology was that between the crystalline or so-called Primary strata, and those which are found in many cases to have been deposited upon them, and, being in part made up of sediments derived from the disintegration of these, were designated Transition and Secondary rocks. While the past forty years have seen great progress in our knowledge of these younger rocks, and while their stratigraphy, the conditions of their deposition, and their geographical distribution and variations have been carefully investigated, the study of the older rocks has been comparatively neglected. This has been due in part to the inherent difficulties of the subject, arising from the general absence of organic remains, and from the greatly disturbed condition of the older strata, but in a greater measure, perhaps, to certain theoretical views respecting the stratified crystalline rocks. In fact, the unlike teachings of two different and opposed schools lead to the common conclusion that the geognostical study of these rocks is unprofitable.

The first of these schools maintains that the rocks in question are, in great part at least, not subordinated to the same structural laws as the uncrystalline formations, but are portions of the original crust of the earth, and that their architecture is due not to aqueous deposition and subsequent mechanical movements, but rather to agencies at work in a cooling igneous mass. The igneous origin of gneisses, petrosilex-porphyries, diorites, serpentines, and even of magnetic and specular iron ores, was held and taught almost universally by our geologists a generation since, and has still its avowed partisans; some maintaining that these various crystalline rocks are portions of the first-formed crust of the planet, underlying the sedimentary rocks, while others imagine

them to be volcanic matter extravasated at more recent dates,—in either case, however, more or less modified by supposed metasomatic processes. By the term metasomatosis are conveniently designated those changes which are not simply internal (diagenesis), but are effected from without,—as a result of which the chemical elements of the original rock are supposed to be either wholly or in part replaced by others from external sources (epigenesis.)

The other school to which allusion has been made, and which, not less than the preceding, has helped to discourage, in the writer's opinion, the intelligent geognostical study of the crystalline stratiform rocks, is that which believes them to be, in great part at least, the result of chemical changes, often metasomatic in their nature, which have been effected in paleozoic and more recent sedimentary beds, obliterating their organic remains, and transforming them into crystalline strata. According to this view, feldspathic, hornblendic and micaceous stratiform crystalline rocks, having similar mineralogical and lithological characters, may belong to widely separated geological periods, and the same geological series may, in one part of its distribution consist of uncrystalline silicious, calcareous, and argillaceous fossiliferous sediments, and in another locality not far remote be found, as the result of subsequent changes effected in these strata, transformed into gneiss, hornblende-schist or mica-schist, by what is vaguely designated as metamorphism.

The recent history of geology abounds in striking illustrations of the fact that in a great number of cases these views have been based on misconceptions in stratigraphy, and without entering into the discussion of the question, it may be said that, in the writer's opinion, careful stratigraphical study will, in all cases, suffice to show the error both of the plutonic and the metamorphic hypothesis of the origin of crystalline rocks. Of these, the former is supported chiefly by the lithological resemblances between certain stratified and unstratified rocks, and by the appearances of stratification occasionally found in these; while the latter is sustained by the analogies offered in cases of local hydrothermal action on sediments, and by the resemblances which recomposed materials frequently offer to their parent crystalline rocks. It is here maintained that the great formations of stratiform crystalline feldspathic, hornblendic and micaceous rocks, which, in various

parts of the world, have been alternately described as plutonic masses, and as metamorphised paleozoic, mesozoic or cenozoic strata, are, in all cases, neptunean rocks, pre-Cambrian or pre-Silurian in age, and that we know of no uncrystalline sediments which are their stratigraphical equivalents.

We have then before us two schools, the one maintaining the secondary origin of a great and by them an undefined portion of the crystalline stratiform rocks, while assigning to certain older (pre-Cambrian) crystalline rocks (of which they admit the existence) either a neptunean or a plutonic origin. The other, or plutonist school, while asserting the plutonic derivation of the greater part of the crystalline formations, accepts, to some extent also, the notion of secondary and neptunean metamorphic schists. It is believed that the above concise statements cover the ground held by the hitherto prevailing neptunean and plutonist schools, neither of which, it is maintained, expresses correctly the present state of our knowledge. In opposition to both of these are the views taught for the last twenty years by the writer, and now accepted by many geologists, which may be thus defined:

1st. All gneisses, petrosilexes, hornblendic and micaceous schists, olivines, serpentines and in fact all silicated crystalline stratified rocks, are of neptunean origin, and are not primarily due to metamorphosis or to metasomatosis either of ordinary aqueous sediments or of volcanic materials[1].

2nd. The chemical and mechanical conditions under which these rocks were deposited and crystallized, whether in shallow water or in abyssal depths (where pressure greatly influences chemical affinities), have not been reproduced to any great extent since the beginning of paleozoic time.

3d. The eruptive rocks, or at least a large part of them, are softened and displaced portions of these ancient neptunean rocks, of which they retain many of the mineralogical and lithological characters.

II. The History of pre-Cambrian Rocks in America.

Coming now to the history of our knowledge of American crys-

[1] It is a question how far the origin of such crystalline aluminous silicates as muscovite, margarodlite, damourite, pyrophyllite, kyanite, fibrolite and andalusite, is to be sought in a process of diagenesis in ordinary aqueous sediments holding the ruins of more or less completely decayed feldspars. Other aluminous rock-forming silicates, such as chlorites and magnesian micas, are however connected through aluminiferous amphiboles with the non-aluminous magnesian silicates, and to all these various magnesian minerals a very different origin must be ascribed.

talline rocks, we find that the lithological characters of the Primary gneissic formation of northern New York were known to Maclure in 1817, and were clearly defined in 1832 by Eaton, who, under the name of the Macomb Mountains, described what have since been called the Adirondacks, and moreover distinguished them from the Primitive rocks of New England. Emmons, in 1842, added much to our lithological knowledge of the crystalline rocks of northern New York, but regarded the gneisses, with their associated limestones, serpentines and iron-ores as all of plutonic origin. Nuttall, who had previously studied the similar rocks in the Highlands of southern New York and New Jersey, had however maintained, as early as 1822, that these had resulted from an alteration of the adjacent paleozoic graywackes and limestones, into which he supposed them to graduate. This view was at the the time opposed by Vanuxem and Keating, but was again set forth in 1843 by Mather, who, while admitting the existence of an older or Primary series of crystalline rocks, conceived a great part of these rocks in southern New York to be altered paleozoic, and distinguished them as Metamorphic rocks. To this latter class he referred all the crystalline stratified rocks of New England, and ended by doubting whether a great part of what he had described as Primary were not to be included in his Metamorphic class. The subsequent labors of Kitchell and of Cooke have, however, clearly established the views of Vanuxem and Keating as to the Primary age alike of the gneisses and the crystalline limestones of the Highlands.

The similar gneissic series in Canada, which was known to Bigsby and to Eaton as an extension of that of northern New York, was noticed by Murray in 1843, and by Logan in 1847, as pre-paleozoic, though apparently of sedimentary origin, and hence, according to them, entitled to be called Metamorphic rather than Primary. It was described by Logan in 1847 as consisting of a lower group of hornblendic gneisses without limestones, and an upper group of similar gneisses, distinguished by interstratified crystalline limestones.

These rocks were found by Logan and by Murray to be overlaid, both on Lake Superior and in the valley of the upper Ottawa, by a series consisting of chloritic and epidotic schists with bedded greenstones, and with conglomerates holding pebbles derived from the ancient gneiss below. This same overlying series had, as early as 1824, been described by Bigsby on Lake Superior, and by

him distinguished from the Primary and classed with Transition rocks.

Labradoritic and hypersthenic rocks, like those previously described by Emmons in the Primary region of northern New York, were in 1853 and 1854 discovered and carefully studied in the Laurentide hills to the north of Montreal, when they were described as being gneissoid in structure, and as interstratified with true gneisses and with crystalline limestones. In 1854 the writer, in concert with Logan, proposed for the ancient crystalline rocks of the Laurentide Mountains, including the lower and upper gneissic groups already mentioned, and the succeeding labradoritic rocks (but excluding the chloritic and greenstone series), the name of Laurentian. In an essay by the writer, in 1855, the oldest gneisses of Scotland and of Scandinavia were, on lithological and stratigraphical grounds, referred to the Laurentian series, and at the same time the name of Huronian was proposed for the chloritic and greenstone series, which had been shown to overlie unconformably the Laurentian in Canada.

Previous to this, in 1851, Foster and Whitney had described the Laurentian and Huronian rocks of Lake Superior as constituting one Azoic system of Metamorphic rocks, with granites, porphyries, and iron-ores of igneous origin, and in 1857 Whitney attacked the two-fold division adopted by the Canadian geological survey, maintaining that the stratified crystalline rocks of the region belong to a single series with a granitic nucleus. The observations of Kimball in 1865, and the later studies of Credner, of Brooks and Pumpelly, and of Irving, have, however, all confirmed the views of the Canadian survey as to the relations of the Laurentian and Huronian in this region.

The Primary age of the Highlands of southern New York, and their extension in what is called the South Mountain, as far as the Schuylkill, was now unquestioned, but the crystalline rocks to the east of this range, while regarded by Eaton and by Emmons as also forming a part of the Primary, were by Mather, as we have already seen, supposed to be altered paleozoic strata. These rocks in New England, with the exception of the quartzites and limestones of the Taconic range, were by him assigned to a horizon above the Trenton limestone of the New York system, and portions of them were conjectured by other geologists, who adopted and extended the views of Mather, to be of Devonian age.

The characteristic crystalline schists of New England and southeastern New York, passing beneath the Mesozoic of New Jersey, reappear in southeastern Pennsylvania, where they were studied and finally described by H. D. Rogers in 1858. According to him, these crystalline schists, while resting unconformably upon an ancient (Hypozoic) gneissic system, were themselves more ancient than the Scolithus-sandstone, which he regarded as the equivalent of the Potsdam. While he supposed these newer crystalline schists, called by him Azoic, to be connected stratigraphically with the base of the Paleozoic series, he nevertheless assigned them to a position below the base of the New York system; thus recognizing in Pennsylvania beneath this horizon, two unconformable groups of crystalline rocks, corresponding stratigraphically, as well as lithologically, with the Laurentian and the Huronian of the Lake Superior region.

The existence among these newer crystalline schists of Pennsylvania, of a series distinct from the Huronian, and representing the White Mountain or Montalban rocks (the Philadelphia and Manhattan gneissic group) had not yet been recognized. Rogers at this time taught the igneous origin of the magnetic iron-ores, the quartz-veins, the serpentines and their associated greenstones in this region. The belief entertained by Rogers of an intimate connection between his upper or Azoic series and the Paleozoic, had its origin, apparently, in the fact of the existence in this region of still another, and newer crystalline series, the Lower Taconic of Emmons, or the Itacolumite group of Lieber, which I have designated Taconian, and propose to consider in a future paper. In it are included the iron-ores of Reading, Cornwall and Dillsburg, Pennsylvania.

The views of H. D. Rogers with regard to the crystalline schists of the Atlantic belt were thus in effect, if not in terms, a return to those held by Eaton and by Emmons, but were in direct opposition to that maintained by Mather, which had been adopted by Logan and by the present writer. The belt of micaceous, chloritic, talcose and epidotic schists, with greenstones and serpentines, the extension of a part of the Azoic of Rogers which, through western New England, is traced into eastern Canada (where it has been known as the Green Mountain range) was, previous to 1862, called by the geological survey of Canada, Altered Hudson-River group. It was subsequently referred to the

Upper Taconic of Emmons, to which Logan at that date gave the name of the Quebec group, assigning it, as has long before been done by Emmons (in 1846), to a horizon between the Potsdam and the Trenton of the New York system.

In 1862 and 1863 appeared, independently, two important papers bearing on the question before us as to the age of these rocks. The first of these was by Thomas Macfarlane, who, after a personal examination of the three regions, compared the Huronian of Lake Huron, and the Green Mountain range of Canada, with portions of the Urschiefer or Primitive schists which, in Norway, intervene between the ancient gneisses and the oldest paleozoic (Lower Cambrian) strata. The second paper was by Bigsby, who was, as we have seen, the earliest student of the Huronian of the northwest, pointing out that these rocks could not in any sense be called Cambrian, but were the equivalent of the Norwegian Urschiefer. The conclusions of Macfarlane were noticed in connection with the views of Keilhau on these rocks of Norway in "The Geology of Canada" in 1863, with farther comparisons between the New England crystalline schists and the Huronian, but official reasons then, and for some years after, prevented the writer from expressing any dissent from the views of the director of the geological survey of Canada.

Meanwhile, the existence of an equivalent series of crystalline schists was being made known in southern New Brunswick, where they were described by G. F. Matthews in 1863, under the name of the Coldbrook group, which included a lower and an upper division. In a joint report of Matthews and Bailey in 1865, these rocks were declared to be overlaid unconformably by the slates in which Hartt had made known a Lower Cambrian (Menevian) fauna, and were compared with the Huronian of Canada. The lower division of the Coldbrook was then described as including a large amount of pink feldspathic quartzite and of bluish and reddish porphyritic slates. In the same report was described, under the name of the Bloomsbury group, a series lithologically similar to the Coldbrook, but apparently resting on the Menevian and overlaid by fossiliferous Upper Devonian beds, into which they were supposed to graduate. The Bloomsbury group was, therefore, regarded as altered Upper Devonian, and its similarity to the pre-Cambrian Coldbrook was explained by supposing both groups to consist in large part of volcanic rocks.

In 1869 and 1870, however, the writer, in company with the gentlemen just named, devoted many weeks to a careful study of these rocks in southern New Brunswick, when it was made apparent that the Bloomsbury group was but a repetition of the Coldbrook on the opposite side of a closely folded synclinal holding Menevian sediments. These two areas of pre-Cambrian rocks were accordingly described by Messrs. Matthews and Bailey in their report to the geological survey of Canada in 1871, as Huronian, in which were also included the similar crystalline rocks belonging to two other areas, which had been previously described by the same observers under the names of the Kingston and Coastal groups, and by them regarded as respectively altered Silurian and Devonian.

After studying the Huronian rocks in southern New Brunswick, and their continuation along the eastern coast of New England, especially in Massachusetts, (where also they are overlaid by Menevian sediments,) the writer, in 1870, announced his conclusion that the crystalline schists of these regions are lithologically and stratigraphically equivalent to those of the Green Mountain range of western New England and eastern Canada. These, he farther declared, in 1871, to be a prolongation of the newer crystalline or Azoic schists of Rogers in Pennsylvania, and the equivalents of the Huronian of the northwest. The pre-Cambrian age of these crystalline schists in eastern Canada has now been clearly proved by the presence of their fragments in the fossiliferous Cambrian strata, in many localities along the northwestern border of the Green Mountain belt, and farther by the recent stratigraphical studies of Selwyn, as announced by him in 1878.

In close association with these Huronian strata in eastern Massachusetts is found a great development of petrosilex rocks, generally jaspery or porphyritic in character, and sometimes fissile, which by Edward Hitchcock were regarded as igneous. These were found to be identical with the rocks designated by Matthews and Bailey as feldspathic quartzites and silicious and porphyritic slates, which form the chief part of the Lower Coldbrook, or inferior division of the Huronian series in New Brunswick. The petrosilexes of Massachusetts were, after careful examination by the writer, described by him in 1870 and in 1871 as indigenous stratified rocks, forming a part of the Huronian series. He, subsequently, in 1871, studied the similar rocks in south-

eastern Missouri, and, in 1872, on the north shore of Lake Superior, but was unable to find them in the Green Mountain belt, or in its southward continuation, until in 1875 he detected them occupying a considerable area in the South Mountain range in southern Pennsylvania. The stratified petrosilex rocks of all these regions were described in a communication to this Association in 1873 as apparently corresponding to the hälleflinta rocks of Sweden, and, having in view their stratigraphical position both in that country and in New Brunswick, they were then "provisionally referred" "to a position near the base of the Huronian series." Their absence in the Huronian belt in western New England, and in the province of Quebec, as well as at several observed points of contact between the Laurentian and the well-defined Huronian in the northwest, led to the suspicion that these hälleflintas might belong to an intermediate series.

C. H. Hitchcock has pointed out that the characteristic Huronian rocks do not form the higher parts of the Green-Mountain range in Vermont, which he conceives to belong to an older gneissic series, a conclusion which the writer regards as premature. Hitchcock, however, in his final report on the geology of New Hampshire, in 1877, adopts the name of Huronian for the crystalline rocks of the Altered Quebec group of Logan, which makes up the chief part of the Green-Mountain range in the province of Quebec, is largely developed along it in Vermont, and appears in a parallel belt farther east, which extends southward into New Hampshire. In his tabular view of the geological groups in this State, Hitchcock assigns to these rocks a thickness of over 12,000 feet, with the name of Upper Huronian, while he designates as Lower Huronian the petrosilex series of eastern Massachusetts, already noticed, where these rocks are of great though undetermined thickness. The similar petrosilex or hälleflinta rocks in Wisconsin, where they have lately been described by Irving as Huronian, have, according to this observer, a thickness, in a single section, of 3,200 feet. They here sometimes become schistose, and are interstratified with micaceous schists, and rest in apparent conformity upon a great mass of quartzites. The general high inclination and disturbed condition both of this series and of the typical Huronian renders the determination of their thickness difficult. The maximum thickness of the Huronian (exclusive

the petrosilex series) to the south of Lake Superior may, according to Major Brooks exceed 12,000 feet, while the estimates of Credner and Murray, respectively, for this region and for the north shore of Lake Huron, are 20,000 and 18,000 feet.

As regards the Laurentian, there exists a certain confusion of nomenclature which requires explanation. As originally described, it includes, as already said, a basal granitoid gneiss without limestones, which the writer has elsewhere designated the Ottawa gneiss, and of which the thickness is necessarily unknown. Succeeding this is the Grenville series of Logan, having for its base a great mass of crystalline limestone, and consisting in addition to this of gneisses, generally hornblendic, and quartzites, interstratified with similar limestones. To this series, as seen north of the Ottawa, Logan assigned an aggregate thickness of over 17,000 feet, though the later measurements of Vennor in the region south of the Ottawa give to it a much greater volume. The geographical distribution of this limestone-bearing Grenville series gives probability to the suggestion of Vennor that it rests unconformably upon the basal Ottawa gneiss.

These two divisions constitute what was designated by Logan in his Geological Atlas, in 1865, the Lower Laurentian, the name of Upper Laurentian or Labradorian being then, for the first time, given by him to a series supposed to overlie unconformably the former, of which it had hitherto been regarded as constituting a part. This third division has already been referred to as characterized by the predominance of great bodies of gneissoid or granitoid rocks, composed chiefly of labradorite or related anorthic feldspars, and apparently identical with the norites of Scandinavia. With these basic rocks are interstratified crystalline limestones, quartzites and gneisses, all of which resemble those of the Grenville series. This upper group, for which the writer in 1871 proposed the name of Norian, was supposed by Logan to be not less than 10,000 feet thick.

For further details of the history of these various groups of pre-Cambrian rocks, and their distribution in North America, the reader is referred to a volume published in 1878 by the Second Geological Survey of Pennsylvania, being Part I of the writer's report on Azoic Rocks, and intended as a historical introduction to the subject.

III. The History of Pre-Cambrian Rocks in Great Britain.

In an address before this Association in 1871, in which the writer maintained the Huronian age of a portion of the crystalline schists of New England and Quebec, he further expressed the opinion, based in part upon his examinations at Holyhead in 1867, and in part upon the study of collections in London, that certain crystalline schists in North Wales would be found to belong to the Huronian series. The rocks in question were by Sedgwick, in 1838, separated from the base of the Cambrian, as belonging to an older series, but were subsequently by Delabeche, Murchison and Ramsay, described and mapped as altered Cambrian strata, with associated intrusive syenites and feldspar-porphyries.

In South Wales, at St. David's in Pembrokeshire, is another area of crystalline rocks which the geological survey of Great Britain had mapped as intrusive syenite, granite and felstone, (petrosilex-porphyry) having Cambrian strata converted into crystalline schists on one side, and unaltered fossiliferous Cambrian beds on the other. So long ago as 1864, Messrs. Hicks and Salter were led to regard the granitoid and porphyritic rocks as pre-Cambrian, and in 1866 concluded that they were not eruptive, but stratified crystalline or metamorphic rocks. After further study, Hicks, in connection with Harkness, published in 1867 additional proofs of the bedded character of these ancient crystalline rocks, and in 1877 the first named observer announced the conclusion that they belong to two distinct and unconformable series. Of these, the older consisted of the granitoid and porphyritic felstone rocks, and the younger of greenish crystalline schists, the so-called Altered Cambrian of the official geologists, both of these being overlaid by the undoubted Lower Cambrian (Harlech and Menevian) of the region, which holds their ruins in its conglomerates. To the lower of the pre-Cambrian groups, Hicks gave the name of Dimetian, and to the upper that of Pebidian. The last, with a measured thickness of 8000 feet, he supposed to be the equivalent of the Huronian, and compared the Dimetian with the Upper Laurentian of Logan.

The similar crystalline rocks of North Wales, already noticed, were now studied by Prof. T. McKenny Hughes of Cambridge, who described them in 1878. These include in Carnarvonshire

and Anglesey the greenish schists which the writer in 1871 referred to the Huronian, (pre-Cambrian of Sedgwick and Altered Cambrian of the geological survey); certain granitoid rocks formerly described as intrusive syenite, and also a reddish feldspar-porphyry, which forms two great ridges in Carnarvonshire. This latter was by Prof. Sedgwick regarded as intrusive, and is moreover mapped as such by the geological survey, though described in Ramsay's memoir on the Geology of North Wales as probably the result of an extreme metamorphism of the lower beds of the Cambrian. The pre-Cambrian age of all these rocks was clearly shown by Hughes, who however considered that the whole might belong to one great stratified series; while Hicks, from an examination of the same region, regarded them as identical with the Dimetian and Pebidian of South Wales.

Dr. Hicks continued his studies in both of these regions in 1878,—being at times accompanied by Dr. Torell of Sweden, Prof. Hughes and Mr. Tawney of Cambridge, and the writer,—and was led to conclude that besides the chloritic schists and greenstones (diorites) of the Pebidian, and the older granitoid and gneissic rocks, there exists, both in North and South Wales, a third independent and intermediate series, to which belong the stratified petrosilex or quartziferous porphyries already noticed. These are sometimes wanting at the base of the Pebidian, and at other times form masses some thousands of feet in thickness. At one locality, near St. David's, a great body of breccia or conglomerate consisting of fragments of the petrosilex united by a crystalline dioritic cement, forms the base of the Pebidian. For this intermediate series, which constitutes the quartziferous porphyry ridges of Carnarvonshire, Dr. Hicks and his friends proposed the name of Arvonian, from Arvonia, the Roman name of the region.

This important conclusion was announced by Dr. Hicks at the meeting of the British Association for the Advancement of Science at Dublin, in August 1878. The writer, previous to attending this meeting, had the good fortune to examine these various pre-Cambrian rocks in parts of Carnarvonshire and Anglesey with Messrs. Torell and Tawney. Subsequently, in company with Dr. Hicks, he visited the region in South Wales where these older rocks had been studied, and was enabled to satisfy himself of the correctness both of the observations and the conclusions of Dr. Hicks, and of the complete parallelism in stratigraphy and in

mineral composition between the pre-Cambrian rocks on the two sides of the Atlantic. It may here be mentioned that Dr. Torell, who, during his visit to America, in 1876, had an opportunity of studying with the writer the petrosilexes of New England and of Pennsylvania, which he regarded as identical with the hälleflinta of Sweden, at once recognized them in the Arvonian series of North Wales.

Of the many areas of these various pre-Cambrian rocks which the writer was enabled to examine in company with Dr. Hicks, may be mentioned the granitoid mass of Twt Hill in the town of Carnarvon, and the succeeding Arvonian to Port Dinorwic, followed, across the Menai Strait, by the Pebidian on the Island of Anglesey, near the Menai bridge. Further on, the Pebidian was again met with near the railway-station of Ty Croes, in the southwest part of the island, succeeded by a large body of Arvonian petrosilex, and a ridge of granitoid gneiss, fragments of which form a breccia at the base of the Arvonian series. The Pebidian is again well displayed at Holyhead.

In South Wales, the similar rocks were examined by him at St. David's, where three small bands of an impure, coarsely crystalline limestone are included in the Dimetian granitoid rock, which is here often exceedingly quartzose. It may be remarked that the Dimetian, as originally defined at this, its first recognized locality, included a great mass of Arvonian petrosilex, the two forming a ridge which extends for some miles in a northeast direction, flanked by Pebidian rocks, which are sometimes in contact with the one and sometimes with the other series. At Clegyr bridge was seen the base of the Pebidian, already mentioned as consisting of a conglomerate of Arvonian fragments. Another belt of the same crystalline rocks was also visited a few miles to the eastward of the last, and not far from Haverfordwest, forming, according to Hicks, a ridge several miles in length and about a mile wide. Where seen at Roch Castle it was found to consist of Arvonian petrosilex, with some granitoid rock near by. The ridge is flanked on the northwest side by Pebidian and Cambrian, and on the southeast by Silurian strata, let down by a fault.

On the shore of Llyn Padarn, near the foot of Snowdon, in North Wales, the porphyritic petrosilex of the Arvonian is again well displayed, while in contact with it, and at the base of the Llanberris (Lower Cambrian) slates, is a conglomerate made up

almost wholly of the petrosilex. This locality was supposed by Prof. Ramsay and others to show that the petrosilex is the result of a metamorphosis of the lower portion of the Cambrian, the conglomerates being regarded as beds of passage. The writer, after a careful examination of the locality, agrees with Messrs. Hicks, Hughes and Bonney that there is no ground for such an opinion, but that the conglomerate marks the base of the Cambrian, which here reposes on Arvonian rocks, and is chiefly made up of their ruins. In like manner, according to Prof. Hughes, the Cambrian in other parts of this region includes beds made up of the *débris* of adjacent granitoid rocks.

These petrosilex-conglomerates of Llyn Padarn are indistinguishable from those found at Marblehead and other localities near Boston, Massachusetts, which have been, in like manner, interpreted as evidences of the secondary origin of the adjacent petrosilex beds, into which they have been supposed to graduate. The writer has, however, always held, in opposition to this view, that these conglomerates are really newer rocks, made up from the ruins of the ancient petrosilex. He has found similar petrosilex conglomerates at various points on the Atlantic coast of New Brunswick, of Lower Cambrian, Silurian and Lower Carboniferous ages, all of which have, in their turn, been regarded by others as formed by the alteration of strata of these geological periods. The evidence now furnished in South Wales of still older (Huronian) beds of petrosilex-conglomerate should be noted by students of North American geology. From observations near Boston, made by one of my former pupils, I have for some time suspected the existence of petrosilex-conglomerates of pre-Cambrian age.

To the eastward of the localities already noticed in Wales are some other small areas of crystalline rocks, including those of the Malverns, and the Wrekin and other hills in Shropshire—all of which appear as islands among Cambrian strata; and those of Charnwood Forest in Leicestershire, which rise in like manner among Triassic rocks. The Wrekin, regarded by Murchison as a post-Cambrian intrusion, has been shown by Callaway to be unconformably overlaid by Lower Cambrian strata, and consists in part of bedded greenstones and in part of banded reddish petrosilex-porphyries, closely resembling the Arvonian of Wales and the corresponding rocks of North America. The geology

of Charnwood has within the past two years been carefully studied by Messrs. Hill and Bonney. The ancient rocks of this region are in part crystalline schists (embracing in the opinion of Dr. Hicks and of the writer, who have seen collections of them, representatives both of the Pebidian and the Arvonian of Wales) and in part eruptive masses, including the granitic rocks of Mount Sorrel.

There is not so far known in the British localities already mentioned, any representative either of the Taconian or Itacolumite group, or of the white micaceous gneisses with micaceous and hornblendic schists which I have designated the Montalban series. I have, however, found the latter well displayed in Ireland, in the Dublin and Wicklow Hills. The probable presence both of this series and of the Huronian in the northwest of Ireland was pointed out by me in 1871, and I have there lately seen the Huronian on Lough Foyle, as also in Scotland in various parts of Argyleshire and Perthshire, as along the Crinan Canal, and in the vicinity of Loch Etive and Loch Awe. From collections sent me by Mr. James Thomson of Glasgow, it appears that both Huronian and Laurentian rocks occur in the island of Islay.

The crystalline schists of Charnwood offer, as was pointed out by Messrs. Hill and Bonney, many resemblances with parts of the Ardennian series of Dumont, of France and Belgium. These, which have been in turn regarded as altered Devonian, Silurian and Lower Cambrian, were, as shown by Gosselet, islands of crystalline rock in the Devonian sea, and in one part include argillites with impressions of Oldhamia and an undetermined graptolite. These rocks have been described in detail in the admirable memoir of de la Vallée Poussin and Renard. The writer had the good fortune in 1878 to visit this region, and, in company with Gosselet and Renard, to examine the section along the valley of the Meuse. The crystalline rocks here displayed greatly resemble those of the American Huronian, in which may be found represented nearly all the types described by the authors in the memoir just mentioned. It would be easy to extend farther this review of the late advances made in the study of the ancient crystalline rocks, but the writer wishes to confine himself to those regions which he has lately examined.

Conclusions.

1. The Pebidian of Hicks has both the lithological characters

and the stratigraphical position of the Huronian of North America, to which he has already compared it.

2. The Arvonian is in like manner identical with the Hälleflinta group of Sweden and with the Petrosilex group of North America, which the writer had provisionally included in the lower part of the Huronian, and which Hitchcock subsequently called Lower Huronian. The fact that there is in Wales a stratigraphical break between it and the overlying Huronian will help to explain the frequent absence of the Arvonian at the base of the Huronian in many of its American localities.

3. The Dimetian, including the granitoid and gneissic rocks with limestone bands, so far as can be seen in the limited outcrops, is indistinguishable from parts of the Laurentian of North America. It was from a misconception that Dr. Hicks in 1878 provisionally compared the Dimetian with the Upper Laurentian, a name at one time used by the geological survey of Canada to designate the Norian series, which, in some parts of North America, overlies unconformably the Laurentian. Hicks at the same time designated as Lower Laurentian the gneiss of the Hebrides (Lewisian of Murchison), which he believed to be distinct from and older than the Dimetian. These two apparently correspond to the Ottawa and Grenville divisions of the proper Laurentian in Canada, and perhaps to the Bojian and Hercynian gneisses of Gümbel in Bavaria.

[The following is a partial list of publications relating to the rocks noticed in part III of this paper. In the Quar. Jour. Geol. Soc. of London are as follows: on these rocks in Wales; Hicks, May 1877, p. 230; Hicks and Davies, Feb. 1878, p. 147, and May 1878, p. 153; Hughes and Bonney, Feb. 1778, p. 137; Hicks and Davies, May 1879, p. 285; Hicks and Bonney, Ibid. p. 295; Bonney, Ibid. p. 309; Bonney and Houghton, Ibid. p. 821; Hughes, Nov. 1879, p. 682; Maw. Aug. 1878, p. 764; also Hicks, rocks of Ross-shire, Nov. 1878, p. 811.

On these rocks in Shropshire in the same journal; Allport, Aug. 1877, p. 449; Callaway, Nov. 1877, p. 653; and Aug. 1878, p. 754: Callaway and Bonney, Nov. 1879, p. 643.

On these rocks in Charnwood Forest in the same journal; Hill and Bonney, Nov. 1877, p. 753, and May 1878, p. 199.

See farther Hunt, Chemical and Geological Essays, pp. 34, 269, 270, 272, 278 and 383; also his Azoic Rocks, part I, (Second Geol. Survey of Penna. 1878), pp. 187, 188.

For the rocks of the Ardennes see Memoire sur les Roches dites plutoniques etc.; de la Vallée Poussin and Renard, (4to pp. 264) from Me-

moires de l'Acad. Royale de la Belgique, 1876; Memoire sur la Comp. Minéralogique du Coticule, Renard, from the same for 1877, and the Mineral and Microscopical Characters of the Belgian Whetstones by Renard, Monthly Microscopical Journal for 1877, vol. XVII, p. 269. Also Gosselet and Malaise, Terrain Silurian des Ardennes, Bull. Acad. Roy. de la Belgique, (2) tom 26, No. 7, 1868; Dewalque, Terrain Cambrian des Ardennes, Ann. Soc. Géol. de la Belgique, tom I, p. 63, and farther Hunt, Chem. and Geol. Essays, p. 270.]

APPENDIX.

Since the above paper was read the writer has received (November 1879) a private communication from Prof. L. W. Bailey, giving his latest results as to the pre-Cambrian rocks of southern New Brunswick, which confirm what has already been said about that region. Bailey separates the Huronian into a lower division, for which he now reserves the name of Coldbrook, consisting chiefly of petrosilex rocks,—and an upper division including the typical Huronian rocks, called by him the Coastal group. He adds that there is between the two, a marked physical break, which is indicated by a stratigraphical discordance, and by the presence in the lower part of the Coastal group of coarse conglomerates made up from the ruins of the Coldbrook or underlying division. This corresponds to the break between the similar Arvonian and Huronian series in South Wales.

At the meeting of the British Association for the Advancement of Science at Sheffield, in August 1879, Dr. Hicks read a paper on the Classification of the pre-Cambrian Rocks, which is published in the Geological Magazine for Oct. 1879. He concludes that the Pebidian is "a group of enormous thickness, which is largely distributed over Great Britain, where it has a prevailing strike of N. N. E. and S. S. W., or from this to N. E. to S. W." In addition to the localities which we have already mentioned in Great Britain, he notes its occurrence in Shropshire and in Charnwood Forest, and also in the northwest of Scotland, where, as elsewhere, it enters largely into the Lower Cambrian conglomerates. The group is concisely described by him as consisting "for the most part of chloritic, talcose, feldspathic and micaceous schistose rocks, alternating with slaty and massive greenstones, dolomitic limestones, serpentines, lava-flows, porcellanites, breccias and conglomerates. It is also traversed frequently by dykes of granite, dolerite, etc."

The conglomerates at the base of the Huronian in Wales are largely made up of masses derived from the Arvonian, with which it "is undoubtedly, at most of the points examined, unconformable." This Arvonian series, Hicks regards as identical with the great Hälleflinta group of the Swedish geologists and with the Petrosilex series which the writer has made known in America. In addition to the localities of it already mentioned in the British Isles, Hicks notes its occurrence in the Harlech

Mountains and the Orkneys, and probably also in the Western Islands and in the Grampians of Scotland. Its strike, in the regions examined by him, is generally about N. and S.

As regards the granitic Dimetian group, the strike of which is N. W. and S. E., or from this to N. and S., Dr. Hicks adds to the localities in Wales, already noticed, its occurrence in the Malvern chain, especially in the Worcester Beacon, and cites Dr. Callaway as authority for its existence in Shropshire. Hicks farther notes its presence at several points in the northwest Highlands of Scotland. From this series of light-colored gneisses, often very quartzose, with limestone bands, he separates, as we have seen, under the name of Lewisian, (proposed by Murchison for the ancient gneisses of Lewis and others of the Hebrides Isles) these, and similar reddish and dark-colored hornblendic gneisses, which are found in parts of the Malvern chain, in the northwest of Ireland, and possibly also in Anglesey. This series, according to Dr. Hicks, is unconformably overlaid by the Dimetian, in which brecciated beds hold fragments of the older Lewisian gneisses. The strike in these older gneisses "is usually E. and W., or some point between that and N. W. and S. E."

Dr. Hicks concludes his recent paper by remarking that the chief part of these ancient rocks in Great Britain "were, until recently, supposed to be either intrusive masses, or altered sediments belonging to tolerably recent times," and adds "it is becoming more and more an acknowledged fact that the metamorphism of great groups of rocks does not take place so readily as was formerly supposed, but that some special conditions, such as do not appear to have prevailed over this area since pre-Cambrian times, were necessary to produce so great a result."

The reader in this connection is referred to the abstract of a memoir communicated by the writer to the British Association at Dublin, August 1878, on The Origin and the Succession of the Crystalline Rocks of North America, which will be found in the *Geological Magazine* for that year (page 466) as well as in *Nature*, vol. 18, page 443.

T. S. H.

NOTICE OF THE OCCURRENCE OF ROCKS REPRESENTING THE MARCELLUS SHALE OF NEW YORK, IN CENTRAL OHIO. By R. P. WHITFIELD, of New York, N. Y.

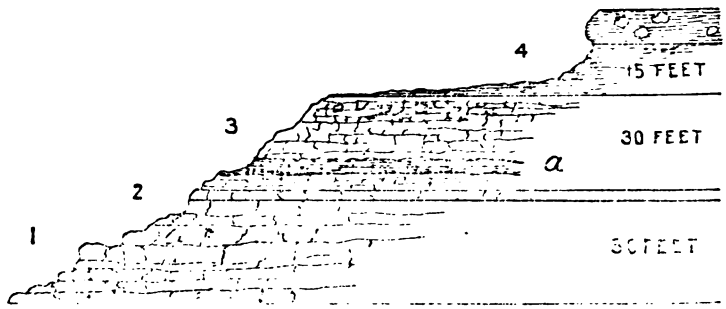
DURING the month of August, 1878, while making some hurried geological observations in the limestone region of central Ohio, in company with Prof. Edward Orton of the Ohio Geological Survey, we came rather unexpectedly upon a bed of dark brown, somewhat fissile, bituminous shale, in the lower part of what has been considered an equivalent of the Delaware limestone of Delaware, Ohio; a formation, which, in the region where we were examining it, consists of thin-bedded, somewhat shaly layers of limestone, although farther north in Delaware County it becomes much heavier and is extensively quarried for building stone.

The peculiar texture of the shale, occurring where I had reason to expect only a light-colored limestone, at once excited my interest, and after a few minutes examination I obtained several pieces, the surfaces of which contained numbers of the flattened shells of *Leiorhynchus limitaris* Vanuxem, two individuals of *Discina minuta* and examples of *Lingula Manni* Hall. The two former species, being strictly characteristic of the Marcellus Shale in New York and occurring in a bituminous shale of similar character, induced me to believe that these shales belonged to that formation. On further examination, we found the shale of like character extending through a thickness of several feet, and to contain great numbers of the *Leiorhynchus*. Having but little time to spare no effort was made to trace the bed beyond the point examined, Prof. Orton promising to have them more thoroughly worked and to furnish a section of the rocks.

On the following day, while examining a section of the same formations at a point nearly opposite the town of Dublin, Ohio, some miles north of the first mentioned locality, the same shale was again recognized at a corresponding horizon, containing the same fossils; the *Leiorhynchus* occurring in abundance, and subsequently *Discina Lodensis* Hall, was also obtained. At this locality, immediately above the shale, and while the bituminous character is still retained in part, the layers become thicker and more calcareous and their surfaces covered with the shells of *Tentaculites scicula* Hall, and *Spirifer gregaria* Clapp. The for-

mer, a very characteristic species of the limestones at Delaware, Ohio.

A section of the rocks at the first mentioned locality, six miles northwest of Columbus, in Perry township and on the east bank of the Scioto, subsequently furnished me by Prof. Orton, is as follows:—



The lower bed, No. 1, of section, is a heavy bedded limestone, about thirty feet thick, representing the Columbus quarries, including the coral beds and those containing the large Cephalopods (Lower Corniferous of the Ohio Geological Reports).

No. 2 is a thin layer of limestone, four to six inches thick, densely filled with teeth, plates and bones of fishes, and known as the "Bone bed."

No. 3. Thirty feet of thin bedded, shaly limestone, the "Delaware beds" of the Ohio Reports. The upper part of this represents the beds at Delaware, Ohio, which contain the large fish remains.

No. 4. About fifteen feet of bluish, somewhat marly shales, the "Olentangy Shales" of the Ohio Reports. This is followed above by the Huron shales, the equivalents of Genesee slate and Portage shales of New York.

Near the lower part of No. 3 (at *a* on section), and only a few feet above the "bone bed," occurs the dark brown shale in question, with its peculiar fossils, which I have no hesitation in pronouncing the equivalent of the MARCELLUS SHALE of New York.

This shale, when weathered, is light ash colored, and not readily distinguished from the thin layers of the limestone above and below; and consequently may be readily overlooked in passing over the ground; but when freshly broken, the lithological features,

although not so deeply colored, yet sufficiently resemble the Marcellus Shale of New York as to be readily recognized, especially when seen with the flattened shells of *Leiorhynchus limitaris* scattered over their surfaces, leaving little doubt of its geological position.

The geological importance of this formation among the rocks of Ohio, may not be readily recognized; but, forming as it does, a dividing line between the lower and upper Devonian, as between the limestone of the upper Helderberg and those which are properly referable to the Hamilton period, it will have great value. It is scarcely probable that it will be found absolutely continuous over the entire limestone region, retaining its bituminous features and carrying its characteristic fossils; but even if recognized at a few localities, which it undoubtedly will be when properly sought for, and its relative position, with regard to the other beds, understood, its great value in tracing out and determining the relative age of many of the Geological and Palæontological features of the formations of the state will be readily conceded; especially as regards the age of some of the large fish remains, which appear to occur in beds above this shale, and would, therefore, seem to be of the age of the Hamilton group of New York, or of the middle instead of the lower Devonian, as heretofore supposed.

The Succession of Glacial Deposits in New England. By Warren Upham, of Nashua, N. H.

The drift presents great diversities in material, stratification and contour. Thus some of the conditions under which its deposits were formed are best illustrated in New England, while other areas may be mentioned, as the St. Lawrence valley, the region of the Great Lakes, the Mississippi valley, and the country between Lake Superior and the Rocky Mountains, which differ much from this district and from each other in their glacial formations. Though diverse in their features, it yet appears that the drift deposits upon all these areas were formed in the same period

and by a common cause, owing their origin directly or indirectly to a vast ice-sheet that overspread the continent north from the Columbia, Missouri and Ohio rivers and the south coast of New England. A comparison of any of these limited districts with the entire field, or with other portions of it, will aid us to understand more fully the conditions that prevailed in this glacial period. It is proposed here to contribute for this end a brief account of the drift in New England, as to the stratigraphical order of its deposits, and as to their geographical succession, or that which would be noticed in passing from the extreme boundary of glacial action northward.

The solid rocks upon which these detrital beds lie are of very uneven contour, rising generally in irregular groups of hills and ranges of highland which vary from one hundred to five hundred feet in height above the valleys, while many tracts are mountains reaching altitudes from one thousand to six thousand feet above the sea. These ledges are everywhere more or less rounded, smoothed and striated, except on steep slopes or mountain-walls facing to the south and southeast which have been sheltered from this abrasion. The course of the striæ is nearly uniform within limited areas, and extends with scarcely any deviation over lowlands and the highest ridges and summits. For the whole of New England it varies between south and southeast. At Portland, Maine, it is S. 20° E.; in the White mountains and in northern New Hampshire, S. 45° E.; at top of Moosilauke and Monadnock, in the same state, S. 20° E.; on Jay Peak, Mt. Mansfield and Camel's Hump, in Vermont, about S. E.; in the northeast corner of Massachusetts, S. 30° to 50° E.; elsewhere in the eastern part of this state, about S. 20° E.; in its central portion, about S. 10° E.; on the mountains of Berkshire county, S. E.; in Rhode Island, nearly due S.; in Connecticut, generally S. S. E. Professors J. D. Dana and C. H. Hitchcock have called attention to a deflection of the striæ along the Connecticut and Merrimack rivers to a course due south or a little west of south, conforming with the direction of these valleys. Exceptions to the general course of striation, diverging from it 10° to 40°, are also occasionally found in all parts of this area.

I. Of the superficial deposits which cover the striated ledges the lowest is a very hard and compact accumulation of boulders,

gravel, sand and clay, indiscriminately mingled, with no marks of stratification, such as is produced by currents of water. The matrix is usually clayey and dark or bluish in color, its iron being mainly in an imperfectly oxidized state. After exposure of sections in this deposit to the weather, this clayey detritus, though filled with rock-fragments, commonly exhibits a kind of cleavage or lamination, being obscurely divided in flakes one-eighth to one-fourth of an inch thick, parallel with the slopes of the surface. The boulders and pebbles which abound throughout this mass are mostly glaciated, having their sides planed to flat surfaces which often retain parallel scratches and furrows like those that mark the underlying rock. Owing to the compactness of this deposit, which requires it to be loosened by a pick before it can be shovelled, it is frequently called "hard-pan." It appears to be the same with the *lower till* of Scotland and Sweden; and all its characteristics indicate that it is a ground-moraine accumulated beneath the moving ice-sheet.

II. Next above this deposit are occasionally found *intercalated beds of clay and sand*, lying between the lower and upper till. At Portland, Maine, these have yielded many species of marine fossils, of species which are still living. The lower till underlying these beds, and the upper till above them, which is three to ten feet thick, though quite unlike, were both undoubtedly of direct glacial origin. It is evident, therefore, that there was here a warm epoch, when the ice-front retreated, after which the arctic climate returned and again caused it to advance, covering these interglacial deposits. In the vicinity of Winnipiseogee lake frequent beds of clay, some of them 30 feet thick, occur between the two kinds of till. These appear to be destitute of organic remains, and their occurrence in some cases upon the sides of isolated hills, 300 feet above the lake, suggests that they were probably deposited in hollows beneath the ice, without such withdrawal and readvance of the glacial sheet.

III. Commonly the lower till, or ground-moraine, is directly overlain by the *upper till*, which appears from its distinguishing features to be material that was contained in the ice-sheet, and was deposited at its melting. The separation between these divisions of the unmodified drift is in most cases at a definite line, with a distinct contrast between the two deposits. The upper till is marked by its looseness; by the usually larger size, and

the rough and angular forms, of its boulders; by its gravelly and sandy detritus, with little admixture of clay; and by its yellowish color, due to the presence of ferric oxide. This deposit generally exhibits no evidence of stratification of any kind; but sometimes, especially near the coast in Maine, and southward to Massachusetts bay, it is partly stratified. Its thickness is usually between one and five feet, but occasionally it reaches ten or even twenty feet.

The boulders which occur plentifully in both the lower and upper till, being of all sizes up to ten feet or rarely twenty to forty feet in diameter, are identical with the rock-formations which are crossed in going from them to the north and northwest, showing that they have been transported in the same course with the striation of the bed-rock. By thus tracing them to their parent ledges, it is found that they have mostly been gathered within twenty miles. The abundance and size of these erratics diminish in proportion to the distance from their source at which we search for them; and the most remote origin which needs to be assigned for any boulders or pebbles found in the drift of New Hampshire during the recent geological survey of that state is eighty-five miles.

The division of the glacial drift as here described, though till recently overlooked, is distinctly shown in New England, as also in Scotland and Sweden, and seems to be due to important differences in the mode of its formation. That much material was pushed along beneath the ice-sheet is proved by the worn surface of the ledges. The flattened and striated stones of the lower till appear to have been the graving tools by which this erosion was effected. The compact character of this deposit, its dark color, and its obscure lamination, also indicate that it was a ground-moraine. On the other hand, it must be seen that the glacial sheet, in its slow progress over hills and mountains, must gather boulders and detritus from their sides, to be carried onward in the ice-mass, which became in this way more or less filled with the materials of the drift, at least to the height of the ridges and peaks which it crossed. At the final disappearance of the ice-sheet these materials contained in it were exposed to the washing of the rills, rivers and floods formed upon its rapidly melting surface. A large part of them were thus removed to be deposited as modified drift, while the portion which remained fell loosely upon

the surface of the ground-moraine or of the interglacial beds over which the ice-sheet had readvanced. This explains why few of the boulders in the upper till have been worn or rounded; and why its iron, long exposed to air and water, has become fully oxidized, giving to this deposit its yellowish color.

IV. The glacial deposits which lie above that last defined are all of the class embraced under the title of modified drift, so called because its materials, derived from the ice-sheet, have been worn, assorted and deposited in layers by currents of water. The oldest of these formations are *kames*, that is, long ridges or knots of interlocking short ridges and mounds, composed of obliquely-bedded gravel and sand, which usually form prolonged series extending from north to south. In the Connecticut and Merrimack valleys, these deposits form ridges, one hundred to two hundred feet high, which are clearly continuous in each case for more than twenty miles. Other series of kames of similar extent have been traced out in northeastern Massachusetts by Rev. G. F. Wright, of Andover, Mass.; but their finest development yet found in America is in Maine, where Prof. George H. Stone, of Kent's Hill, in that state, has traced twenty or more series which vary in length from five to one hundred miles. The height of these ridges is usually less than one hundred feet to which they rise steeply, the slopes of their sides varying from 15° to 40°. Their material in some cases is almost entirely very coarse gravel with scarcely any layers of sand, so that they present no distinct stratification. In these portions, however, they are shown to be deposits from currents of water because their pebbles and boulders, though from one to three feet in diameter, are mostly waterworn, having their sides and angles considerably smoothed and rounded, being quite different from the rough fragments of the upper till and equally unlike the bevelled forms of stones in the lower till. The predominance of pebbles, and the rare occurrence or entire absence of very large blocks which abound in the adjacent unmodified drift, also indicate that these deposits were brought by torrents which could only transport rocks of a limited size, and which swept onward the greater part of the fine gravel and sand. Elsewhere these kames consist of interstratified gravel and sand which mark seasons of alternately rapid and quiet currents. Wherever deep valleys are found extending from north to south kames seem to occur oftener in these depressions than upon the

intervening highland; but where no well-marked valleys exist they are found threading their way in a south or south-southeast course among the scattered hills, often crossing them, with undulations of one or two hundred feet. The origin of these remarkable gravel ridges appears to have been from glacial rivers which flowed from the surface of the melting ice-sheet laden with gravel, sand and clay. Near the edge of the ice which formed walls upon each side of these floods they deposited the heaviest part of their burden, and when the ice beside and beneath them disappeared these beds were left as ridges and mounds of irregularly stratified gravel and sand.

V. In a few places, plateaus of modified drift of similar origin with the kames lie between streams whose valleys seem never to have been filled. The plain of coarse gravel and sand about Willand pond in Dover, N. H., two hundred feet above the Salmon Falls and Cochecho rivers on each side, appears to be of this class, having been laid down by glacial floods while these adjoining areas were occupied by higher ice-fields. A more notable example of the same kind is the extreme portion of Cape Cod, where the townships of Eastham, Wellfleet and Truro appear to have been formed in this manner by floods poured down from the retreating glacial sheet which still bordered them with walls of ice. Massive hills and broad ridges of modified drift, which probably also belong in this class, occur in New Hampshire near the coast, and at Newburyport, Mass.

VI. Overlying the sides of the kames and of the kame-like plains and broad ridges, and sometimes quite covering them, is the usually much more extensive and conspicuous *valley drift*, consisting of gravel, sand and clay, found in all valleys that extend southward in New England. In portions of this area where such depressions do not exist, these deposits were spread in plains often several miles wide which have been subsequently intersected by channels of drainage. These level beds of modified drift appear to have been supplied from the material held in the ice-sheet, and were borne to their present place and laid down by the floods which descended from it at its final melting. Their deposition was in front of the retreating edge of the ice-fields, and they generally rest upon the upper till.

In the principal valleys these beds have been excavated, often to the depth of one hundred to one hundred and fifty feet, by the

present streams, which in this process of erosion have formed successive flood-plains, each lower than the preceding. Each of these in its turn has been cut into by the deepening channel, its remnants being left as terraces on the sides of the valley.

The finer portions of these deposits were carried far beyond the termination of the ice-sheet, and near the coast in eastern Massachusetts, New Hampshire and Maine form fossiliferous marine beds of sand and clay. These occur at but slight elevation above our present sea-level near Boston; at heights from thirty to seventy-five feet above the sea in Portsmouth and Greenland, N. H.; and in Maine at heights which increase northward to two hundred feet or more.

Terminal Moraines. Having now considered the successive deposits of the glacial period in New England in their stratigraphical order, we may next take a survey of this area as to the distribution of these formations. In this respect it is most important to notice its southern border and Long Island which exhibit the terminal moraines of the ice-sheet. Across northern New Jersey the margin of the glacial drift is marked by a series of very irregular hills, composed of till with occasional portions of modified drift, which have been traced by Professors Cook and Smock from the Delaware river a few miles above Easton, by Hackettstown, Dover and Morristown to Perth Amboy. Striæ, till and boulders find their southern boundary at this terminal moraine, which for the twelve miles between Plainfield and Perth Amboy is well known by the name of Short hills. Its continuation is plainly traceable across Staten island, and it forms the sites of Forts Tompkins and Hamilton on the opposite sides of the Narrows. On Long Island this series of morainic hills is very finely exhibited, extending from Fort Hamilton for the first twenty-four miles in a nearly east-northeast course to Roslyn; from which it runs nearly due east sixty miles to Canoe Place and the Shinnecock hills; next it turns northeast about eight miles to near Sag Harbor; and thence its course is east and east-northeast about twenty-five miles to Montauk point, at the east extremity of the island. This range of hills is bordered along most of this distance by nearly level plains on both sides, and so striking is its topographic effect that long ago it came to be commonly called "the backbone of the island."

From the Narrows to Roslyn this moraine ranges from one

hundred to two hundred and fifty feet in height, and it is mainly composed of unmodified drift which shows on the surface the characteristic features of the upper till, but in deep excavations is found to contain glaciated pebbles and boulders. A part of it thus appears to have been brought in the ice-mass and dumped at its border, while other portions were pushed forward from beneath the glacial sheet. This range is of quite irregular contour, presenting a succession of hillocks, ridges and hollows. It is well seen in the hilly portions of Greenwood cemetery and Prospect park, and at Ridgewood reservoir. It passes within about a mile north of Jamaica and Creedmoor, and holds Success or Lakeville pond near its top.

Eastward from Roslyn this range is almost wholly composed of modified drift, being waterworn gravel and sand with few or no boulders. These deposits are distinctly stratified, but often with oblique bedding, and seem to constitute the entire mass of hills from two hundred to nearly four hundred feet high. Harbor hill, the highest on Long Island, situated a half mile east from Roslyn, is of this kind, its top being three hundred and eighty-four feet above the sea. In the same class are also Jane's hill, the highest of the West hills, three hundred and fifty-four feet; Ruland's, the highest of the Coram hills, three hundred and forty feet; and Osborn's or Bald hill, a few miles southwest from Riverhead, two hundred and ninety-three feet in height. These stratified deposits appear to have been accumulated at the edge of the ice-sheet, by floods which flowed down from its surface when a warmer climate began to urge its retreat. The portion of this moraine which forms the peninsula of Montauk ten miles long and rising in hills one hundred and fifty to two hundred feet high, is also distinctly stratified, as shown in the cliffs undermined by the sea along its south shore; but these beds of gravel, sand and clay contain frequent embedded boulders, which are also spread very abundantly upon the surface. These may indicate that during or after the accumulation of the stratified drift, the ice-sheet advanced here, covering its fluvial deposits with a mantle of upper till.

The part of Long Island south of this series of hills consists of nearly level plains of fine gravel and sand, five to ten miles in width and extending a hundred miles in length. Their north portion at the foot of the terminal moraine is from fifty to one

hundred and fifty feet above the sea, from which height they slope gently southward. These plains are crossed from north to south by numerous ancient water-courses, ten to twenty-five feet deep and one hundred to three hundred feet wide. Mr. Elias Lewis, jr., of Brooklyn, has explored these, finding thirty between East New York and Riverhead. Most of them are now dry except that they contain rivulets within one to three miles from the coast. In some cases these channels are found to continue beneath the southern bays to the beach-ridge by which they are divided from the open ocean. These plains were probably deposited by the floods which heaped the hills of modified drift along the ice-margin; and the water-courses mentioned appear to have been formed by the same floods at their lower stages. The continuation of these channels below our sea-level shows that the ocean at the latitude of Long Island did not rise so high upon the land in the glacial period as now; though it appears at the same time to have stood above its present height north from Massachusetts bay.

The moraine which we have described from Delaware river to Montauk point next appears in Block island, which is a knot of irregularly grouped drift-hills, one hundred to two hundred feet high, closely resembling those of Montauk in their stratified character with boulders embedded in them and strown plentifully over their top. It next rises above the sea at No Man's Land and in the northwest part of Martha's Vineyard, where it forms the surface of Gay Head and makes prominent ranges of hills, two hundred to three hundred feet high. It is here composed of unmodified drift with many boulders, and overlies fossiliferous Tertiary strata. Near Vineyard Haven this moraine bends southeastward, and is represented by Chappaquiddick island, at the east end of Martha's Vineyard, by Tuckernuck island, and by Saul's hills and Sankaty Head on Nantucket. At the south side of these hills on Martha's Vineyard and Nantucket islands are plains of modified drift crossed by frequent water-courses of a former period, similar to those of Long Island. These continue beneath the sea which fills their lower portion with long bays or ponds; for in many cases these arms of the sea have become shut in by the formation of a beach-ridge. All the numerous ponds shown by maps along the south shore of these islands are of this class; proving, as already noticed, that the ocean here was lower than now when these deposits were made.

A later terminal moraine of the ice-sheet, accumulated during a halt in its final retreat, forms the north shore of Long Island from Port Jefferson to Orient point, rising in hills one hundred to two hundred feet high. Except in the vicinity of Greenport and Orient, this consists of modified drift with only occasional boulders. It is separated from the extreme moraine by a continuous series of plains, five or six miles wide, which slope southward and are crossed from north to south by old channels of drainage, as on the south side of this island. This second moraine north of Orient, and in Plum and Fisher's islands, which are its continuation, consists of unmodified drift like the upper till, with very abundant boulders. The same character marks it in Rhode Island, where it is finely developed in a series of hills, one hundred to two hundred feet high, of very broken contour, which extend near the shore from Watch hill, at the southwest corner of the state, to a point about two miles west of Point Judith, where this moraine appears to turn southward, passing beneath the ocean. Its next appearance is in the Elizabeth islands which form a chain fifteen miles long with an average width of one mile. Here its material is unmodified drift, including both upper and lower till, which form hills from fifty to one hundred and seventy-five feet high, with the broken outlines and alternate elevations and depressions that usually mark these morainic deposits. In the Elizabeth islands this series has an east-northeast course, but in the next few miles on the peninsula of Cape Cod, it gradually bends to a direction nearly due north, though continuing with its width, height, material and contour unchanged. Its north course continues about ten miles to a point about a mile south from North Sandwich, where it turns at a right angle to a course a few degrees south of east, and thence extends along the west-to-east portion of the cape to its east shore at Orleans. The highest part of this range is near its angle in Sandwich, where it rises two hundred to three hundred feet above the sea. This portion consists principally of modified drift with few boulders. Farther east it is partly modified drift, often with numerous boulders embedded in it and sprinkled upon its surface; and partly unmodified, with very abundant angular blocks, such as occur in the upper till.

South of this line of hills on Cape Cod are plains of gravel and sand, five to ten miles wide and thirty miles long, which have their upper edge, next to the moraine, seventy-five to two hundred feet

above sea-level, to which they descend by a gradual slope, so that their southern edge at the shore is only ten to forty feet high. These plains are crossed by ancient north-to-south water-courses, which are partly filled by arms of the sea, as on Long Island, Martha's Vineyard and Nantucket. It is also to be noted that they occur most abundantly in Falmouth and Mashpee, directly in the line of drainage from the angle of the terminal moraine to which the ice-sheet sloped from both sides and to which consequently its floods converged. The medial moraine, formed where the ice-currents pushed together north of this angle, appears in Manomet and Pine hills, which constitute a gigantic ridge of coarsely rocky unmodified drift in the east part of Plymouth, four miles long from north to south, with a continuous height three hundred to four hundred feet above the sea. The second terminal moraine at the Elizabeth islands is five miles from the extreme moraine on Martha's Vineyard, but their distance apart increases eastward to thirty miles between Nantucket and Orleans.

Lenticular Hills. Farther to the north in New England no similar series of drift-hills has been discovered, and it appears that in general the retreat of the ice was too rapid to permit their accumulation, the direct glacial deposits being spread somewhat uniformly in the lower and upper till. The lower till occurs in patches or sheets which probably cover half of this area. They are of variable thickness, ranging from two or three to fifty feet or more in depth. This deposit is also found forming massive, oval hills which have their longer axis parallel with the striæ marked upon the adjoining rocks. These hills are from a few hundred feet to a mile in length, with about two-thirds as great width, while their height correspondingly varies from twenty-five to two hundred feet. But whatever may be their size they are singularly alike in form, having steep sides crowned by a gracefully rounded top, so that they present a very smooth and regular contour. From this resemblance in shape to an elliptical convex lens Professor Hitchcock has denominated them *lenticular hills*, to distinguish these accumulations of the lower till from its flattened or undulating sheets which are found in all parts of New England.

The lenticular hills occur frequently upon certain areas which vary from five to ten miles in width and from ten to thirty miles in length. One of these areas includes Boston and its harbor,

and extends from five to fifteen miles on all sides of that city. Another area of lenticular hills occurs in the north part of Essex county, Mass., reaching northeast into Rockingham county in New Hampshire; while two other belts extend from northeast to southwest and from north to south in Hillsborough and Cheshire counties of the latter state. Between these areas are others of equal or greater width which are entirely destitute of such hills, or have only here and there one, quite isolated from any others of its kind, but sometimes as prominent and typical as any in the tracts where they abound. These hills have not been sufficiently looked for to permit us to state whether they occur in many other portions of New England. In the region where they have been explored their peculiar distribution does not appear to be due to the character of the adjacent stratified rocks, nor to the contour of the land, for they occur in equal abundance on low and otherwise level tracts near the sea, and fifteen hundred feet above it among ledgy hills at the height of land between Merrimack and Connecticut rivers. They seem as likely also to be found upon one side as another of any prominent mountain or hill-range. If their distribution has been independent of these conditions, as appears to be true, we can only say that it probably resulted in some unexplained way from movements of the ice-sheet, beneath which these massive hills were built up, as is shown by their trend and material.

The upper till in New England forms a universal mantle, generally less than five feet in depth, covering hills and valleys, ground-moraine and ledges, except that small outcrops of rock appear frequently in all parts of this area. In valleys and upon many comparatively level tracts, these deposits of boulder-drift are concealed beneath stratified gravel, sand and clay, which appear to be somewhat less directly of glacial origin, having been brought by rivers from the melting ice-sheet.

On the Geological Action of the Humus Acids.

By Alexis A. Julien, of New York, N. Y.

I. Introduction.

§ 1. *The Humus layer.*—Throughout all geological periods, whose records are within our observation, even the Archæan, a zone of gentle but ceaseless chemical action has enveloped the earth, whose efficiency in extensive subterranean alteration seems yet to be but partially recognized. Now, as in the past, it is represented by the thin sub-aërial layer of humus, which constitutes the soil of forests and savannas, and the muck of fresh and brackish-water swamps. Intervening between the crystalline mineral substances of unstable composition below and the layer of atmosphere above—a storehouse of gaseous and liquid agencies of decomposition and removal—this layer of humus has been the medium of continual reaction and change. Especially has it served as a laboratory for the production of a series of acids, which have been constantly transferred over the surface by streams and within the interior by percolating solutions, and as constantly renewed.

§ 2. *Efficiency of organic acids.*—A recently published investigation[1] by a Fellow of this Association has directed attention to a power of decomposition and corrosion, little suspected, of several common organic acids, both in artificial application and in the field of geological phenomena. From the data there given of the results of his examination of two hundred minerals, the brief tabular statement (page 312) presents the reactions nearly allied to those obtaining in nature: the minerals selected being those of most common occurrence in rocks and veins.

In regard to these two methods of treatment, negative results were obtained with a large number of minerals, *e. g.*, pyrite, chalcopyrite, augite, hornblende, the feldspars, micas, olivine, fluorite, etc.; but the nature and strength of the solvent employed, and the brief duration of each trial, seem at present insufficient to justify generalization, notwithstanding the suggestiveness of certain results.

My present purpose is to extend the series of illustrations of the character and extent of the geological phenomena, both from

[1] "Application of Organic Acids to the Examination of Minerals," H. Carrington Bolton, Ann. N. Y. Acad. Sci., 1877-78, I, 1, 153.

intervening highland; but where no well-marked valleys exist they are found threading their way in a south or south-southeast course among the scattered hills, often crossing them, with undulations of one or two hundred feet. The origin of these remarkable gravel ridges appears to have been from glacial rivers which flowed from the surface of the melting ice-sheet laden with gravel, sand and clay. Near the edge of the ice which formed walls upon each side of these floods they deposited the heaviest part of their burden, and when the ice beside and beneath them disappeared these beds were left as ridges and mounds of irregularly stratified gravel and sand.

V. In a few places, plateaus of modified drift of similar origin with the kames lie between streams whose valleys seem never to have been filled. The plain of coarse gravel and sand about Willand pond in Dover, N. H., two hundred feet above the Salmon Falls and Cochecho rivers on each side, appears to be of this class, having been laid down by glacial floods while these adjoining areas were occupied by higher ice-fields. A more notable example of the same kind is the extreme portion of Cape Cod, where the townships of Eastham, Wellfleet and Truro appear to have been formed in this manner by floods poured down from the retreating glacial sheet which still bordered them with walls of ice. Massive hills and broad ridges of modified drift, which probably also belong in this class, occur in New Hampshire near the coast, and at Newburyport, Mass.

VI. Overlying the sides of the kames and of the kame-like plains and broad ridges, and sometimes quite covering them, is the usually much more extensive and conspicuous *valley drift*, consisting of gravel, sand and clay, found in all valleys that extend southward in New England. In portions of this area where such depressions do not exist, these deposits were spread in plains often several miles wide which have been subsequently intersected by channels of drainage. These level beds of modified drift appear to have been supplied from the material held in the ice-sheet, and were borne to their present place and laid down by the floods which descended from it at its final melting. Their deposition was in front of the retreating edge of the ice-fields, and they generally rest upon the upper till.

In the principal valleys these beds have been excavated, often to the depth of one hundred to one hundred and fifty feet, by the

present streams, which in this process of erosion have formed successive flood-plains, each lower than the preceding. Each of these in its turn has been cut into by the deepening channel, its remnants being left as terraces on the sides of the valley.

The finer portions of these deposits were carried far beyond the termination of the ice-sheet, and near the coast in eastern Massachusetts, New Hampshire and Maine form fossiliferous marine beds of sand and clay. These occur at but slight elevation above our present sea-level near Boston; at heights from thirty to seventy-five feet above the sea in Portsmouth and Greenland, N. H.; and in Maine at heights which increase northward to two hundred feet or more.

Terminal Moraines. Having now considered the successive deposits of the glacial period in New England in their stratigraphical order, we may next take a survey of this area as to the distribution of these formations. In this respect it is most important to notice its southern border and Long Island which exhibit the terminal moraines of the ice-sheet. Across northern New Jersey the margin of the glacial drift is marked by a series of very irregular hills, composed of till with occasional portions of modified drift, which have been traced by Professors Cook and Smock from the Delaware river a few miles above Easton, by Hackettstown, Dover and Morristown to Perth Amboy. Striæ, till and boulders find their southern boundary at this terminal moraine, which for the twelve miles between Plainfield and Perth Amboy is well known by the name of Short hills. Its continuation is plainly traceable across Staten island, and it forms the sites of Forts Tompkins and Hamilton on the opposite sides of the Narrows. On Long Island this series of morainic hills is very finely exhibited, extending from Fort Hamilton for the first twenty-four miles in a nearly east-northeast course to Roslyn; from which it runs nearly due east sixty miles to Canoe Place and the Shinnecock hills; next it turns northeast about eight miles to near Sag Harbor; and thence its course is east and east-northeast about twenty-five miles to Montauk point, at the east extremity of the island. This range of hills is bordered along most of this distance by nearly level plains on both sides, and so striking is its topographic effect that long ago it came to be commonly called "the backbone of the island."

From the Narrows to Roslyn this moraine ranges from one

hundred to two hundred and fifty feet in height, and it is mainly composed of unmodified drift which shows on the surface the characteristic features of the upper till, but in deep excavations is found to contain glaciated pebbles and boulders. A part of it thus appears to have been brought in the ice-mass and dumped at its border, while other portions were pushed forward from beneath the glacial sheet. This range is of quite irregular contour, presenting a succession of hillocks, ridges and hollows. It is well seen in the hilly portions of Greenwood cemetery and Prospect park, and at Ridgewood reservoir. It passes within about a mile north of Jamaica and Creedmoor, and holds Success or Lakeville pond near its top.

Eastward from Roslyn this range is almost wholly composed of modified drift, being waterworn gravel and sand with few or no boulders. These deposits are distinctly stratified, but often with oblique bedding, and seem to constitute the entire mass of hills from two hundred to nearly four hundred feet high. Harbor hill, the highest on Long Island, situated a half mile east from Roslyn, is of this kind, its top being three hundred and eighty-four feet above the sea. In the same class are also Jane's hill, the highest of the West hills, three hundred and fifty-four feet; Ruland's, the highest of the Coram hills, three hundred and forty feet; and Osborn's or Bald hill, a few miles southwest from Riverhead, two hundred and ninety-three feet in height. These stratified deposits appear to have been accumulated at the edge of the ice-sheet, by floods which flowed down from its surface when a warmer climate began to urge its retreat. The portion of this moraine which forms the peninsula of Montauk ten miles long and rising in hills one hundred and fifty to two hundred feet high, is also distinctly stratified, as shown in the cliffs undermined by the sea along its south shore; but these beds of gravel, sand and clay contain frequent embedded boulders, which are also spread very abundantly upon the surface. These may indicate that during or after the accumulation of the stratified drift, the ice-sheet advanced here, covering its fluvial deposits with a mantle of upper till.

The part of Long Island south of this series of hills consists of nearly level plains of fine gravel and sand, five to ten miles in width and extending a hundred miles in length. Their north portion at the foot of the terminal moraine is from fifty to one

hundred and fifty feet above the sea, from which height they slope gently southward. These plains are crossed from north to south by numerous ancient water-courses, ten to twenty-five feet deep and one hundred to three hundred feet wide. Mr. Elias Lewis, jr., of Brooklyn, has explored these, finding thirty between East New York and Riverhead. Most of them are now dry except that they contain rivulets within one to three miles from the coast. In some cases these channels are found to continue beneath the southern bays to the beach-ridge by which they are divided from the open ocean. These plains were probably deposited by the floods which heaped the hills of modified drift along the ice-margin; and the water-courses mentioned appear to have been formed by the same floods at their lower stages. The continuation of these channels below our sea-level shows that the ocean at the latitude of Long Island did not rise so high upon the land in the glacial period as now; though it appears at the same time to have stood above its present height north from Massachusetts bay.

The moraine which we have described from Delaware river to Montauk point next appears in Block island, which is a knot of irregularly grouped drift-hills, one hundred to two hundred feet high, closely resembling those of Montauk in their stratified character with boulders embedded in them and strown plentifully over their top. It next rises above the sea at No Man's Land and in the northwest part of Martha's Vineyard, where it forms the surface of Gay Head and makes prominent ranges of hills, two hundred to three hundred feet high. It is here composed of unmodified drift with many boulders, and overlies fossiliferous Tertiary strata. Near Vineyard Haven this moraine bends southeastward, and is represented by Chappaquiddick island, at the east end of Martha's Vineyard, by Tuckernuck island, and by Saul's hills and Sankaty Head on Nantucket. At the south side of these hills on Martha's Vineyard and Nantucket islands are plains of modified drift crossed by frequent water-courses of a former period, similar to those of Long Island. These continue beneath the sea which fills their lower portion with long bays or ponds; for in many cases these arms of the sea have become shut in by the formation of a beach-ridge. All the numerous ponds shown by maps along the south shore of these islands are of this class; proving, as already noticed, that the ocean here was lower than now when these deposits were made.

A later terminal moraine of the ice-sheet, accumulated during a halt in its final retreat, forms the north shore of Long Island from Port Jefferson to Orient point, rising in hills one hundred to two hundred feet high. Except in the vicinity of Greenport and Orient, this consists of modified drift with only occasional boulders. It is separated from the extreme moraine by a continuous series of plains, five or six miles wide, which slope southward and are crossed from north to south by old channels of drainage, as on the south side of this island. This second moraine north of Orient, and in Plum and Fisher's islands, which are its continuation, consists of unmodified drift like the upper till, with very abundant boulders. The same character marks it in Rhode Island, where it is finely developed in a series of hills, one hundred to two hundred feet high, of very broken contour, which extend near the shore from Watch hill, at the southwest corner of the state, to a point about two miles west of Point Judith, where this moraine appears to turn southward, passing beneath the ocean. Its next appearance is in the Elizabeth islands which form a chain fifteen miles long with an average width of one mile. Here its material is unmodified drift, including both upper and lower till, which form hills from fifty to one hundred and seventy-five feet high, with the broken outlines and alternate elevations and depressions that usually mark these morainic deposits. In the Elizabeth islands this series has an east-northeast course, but in the next few miles on the peninsula of Cape Cod, it gradually bends to a direction nearly due north, though continuing with its width, height, material and contour unchanged. Its north course continues about ten miles to a point about a mile south from North Sandwich, where it turns at a right angle to a course a few degrees south of east, and thence extends along the west-to-east portion of the cape to its east shore at Orleans. The highest part of this range is near its angle in Sandwich, where it rises two hundred to three hundred feet above the sea. This portion consists principally of modified drift with few boulders. Farther east it is partly modified drift, often with numerous boulders embedded in it and sprinkled upon its surface; and partly unmodified, with very abundant angular blocks, such as occur in the upper till.

South of this line of hills on Cape Cod are plains of gravel and sand, five to ten miles wide and thirty miles long, which have their upper edge, next to the moraine, seventy-five to two hundred feet

above sea-level, to which they descend by a gradual slope, so that their southern edge at the shore is only ten to forty feet high. These plains are crossed by ancient north-to-south water-courses, which are partly filled by arms of the sea, as on Long Island, Martha's Vineyard and Nantucket. It is also to be noted that they occur most abundantly in Falmouth and Mashpee, directly in the line of drainage from the angle of the terminal moraine to which the ice-sheet sloped from both sides and to which consequently its floods converged. The medial moraine, formed where the ice-currents pushed together north of this angle, appears in Manomet and Pine hills, which constitute a gigantic ridge of coarsely rocky unmodified drift in the east part of Plymouth, four miles long from north to south, with a continuous height three hundred to four hundred feet above the sea. The second terminal moraine at the Elizabeth islands is five miles from the extreme moraine on Martha's Vineyard, but their distance apart increases eastward to thirty miles between Nantucket and Orleans.

Lenticular Hills. Farther to the north in New England no similar series of drift-hills has been discovered, and it appears that in general the retreat of the ice was too rapid to permit their accumulation, the direct glacial deposits being spread somewhat uniformly in the lower and upper till. The lower till occurs in patches or sheets which probably cover half of this area. They are of variable thickness, ranging from two or three to fifty feet or more in depth. This deposit is also found forming massive, oval hills which have their longer axis parallel with the striæ marked upon the adjoining rocks. These hills are from a few hundred feet to a mile in length, with about two-thirds as great width, while their height correspondingly varies from twenty-five to two hundred feet. But whatever may be their size they are singularly alike in form, having steep sides crowned by a gracefully rounded top, so that they present a very smooth and regular contour. From this resemblance in shape to an elliptical convex lens Professor Hitchcock has denominated them *lenticular hills*, to distinguish these accumulations of the lower till from its flattened or undulating sheets which are found in all parts of New England.

The lenticular hills occur frequently upon certain areas which vary from five to ten miles in width and from ten to thirty miles in length. One of these areas includes Boston and its harbor,

and extends from five to fifteen miles on all sides of that city. Another area of lenticular hills occurs in the north part of Essex county, Mass., reaching northeast into Rockingham county in New Hampshire: while two other belts extend from northeast to southwest and from north to south in Hillsborough and Cheshire counties of the latter state. Between these areas are others of equal or greater width which are entirely destitute of such hills, or have only here and there one, quite isolated from any others of its kind, but sometimes as prominent and typical as any in the tracts where they abound. These hills have not been sufficiently looked for to permit us to state whether they occur in many other portions of New England. In the region where they have been explored their peculiar distribution does not appear to be due to the character of the adjacent stratified rocks, nor to the contour of the land, for they occur in equal abundance on low and otherwise level tracts near the sea, and fifteen hundred feet above it among ledgy hills at the height of land between Merrimack and Connecticut rivers. They seem as likely also to be found upon one side as another of any prominent mountain or hill-range. If their distribution has been independent of these conditions, as appears to be true, we can only say that it probably resulted in some unexplained way from movements of the ice-sheet, beneath which these massive hills were built up, as is shown by their trend and material.

The upper till in New England forms a universal mantle, generally less than five feet in depth, covering hills and valleys, ground-moraine and ledges, except that small outcrops of rock appear frequently in all parts of this area. In valleys and upon many comparatively level tracts, these deposits of boulder-drift are concealed beneath stratified gravel, sand and clay, which appear to be somewhat less directly of glacial origin, having been brought by rivers from the melting ice-sheet.

On the Geological Action of the Humus Acids. By Alexis A. Julien, of New York, N. Y.

I. Introduction.

§ 1. *The Humus layer.*—Throughout all geological periods, whose records are within our observation, even the Archæan, a zone of gentle but ceaseless chemical action has enveloped the earth, whose efficiency in extensive subterranean alteration seems yet to be but partially recognized. Now, as in the past, it is represented by the thin sub-aërial layer of humus, which constitutes the soil of forests and savannas, and the muck of fresh and brackish-water swamps. Intervening between the crystalline mineral substances of unstable composition below and the layer of atmosphere above—a storehouse of gaseous and liquid agencies of decomposition and removal—this layer of humus has been the medium of continual reaction and change. Especially has it served as a laboratory for the production of a series of acids, which have been constantly transferred over the surface by streams and within the interior by percolating solutions, and as constantly renewed.

§ 2. *Efficiency of organic acids.*—A recently published investigation[1] by a Fellow of this Association has directed attention to a power of decomposition and corrosion, little suspected, of several common organic acids, both in artificial application and in the field of geological phenomena. From the data there given of the results of his examination of two hundred minerals, the brief tabular statement (page 312) presents the reactions nearly allied to those obtaining in nature: the minerals selected being those of most common occurrence in rocks and veins.

In regard to these two methods of treatment, negative results were obtained with a large number of minerals, *e. g.*, pyrite, chalcopyrite, augite, hornblende, the feldspars, micas, olivine, fluorite, etc.; but the nature and strength of the solvent employed, and the brief duration of each trial, seem at present insufficient to justify generalization, notwithstanding the suggestiveness of certain results.

My present purpose is to extend the series of illustrations of the character and extent of the geological phenomena, both from

[1] "Application of Organic Acids to the Examination of Minerals," H. Carrington Bolton, Ann. N. Y. Acad. Sci., 1877-78, I, 1, 153.

recent personal observations and from published but hitherto disconnected facts. It will be understood that although little or no

MINERALS DECOMPOSED (IN FINE POWDER) BY A SATURATED SOLUTION OF CITRIC ACID.

IN THE COLD.

A. *Without evolution of Gas.*	B. *With liberation of CO_2.*	C. *With liberation of H_2S.*	D. *With separation of SiO_2.*
Clausthalite, Leucopyrite, Brucite, Pyromorphite,* Vivianite,! Wavellite, Anglesite, Brochantite.!	Calcite,! Dolomite,* Gurhofite,! Ankerite,* Rhodochrosite,* Smithsonite,* Aragonite,! Witherite,! Strontianite,! Cerussite,! Malachite,! Azurite.*	Stibnite, Galenite, Sphalerite, Pyrrhotite.	Wollastonite, Rhodonite,! Chrysolite, Willemite,!‡ Nephelite, Chondrodite, Pectolite,!‡ Laumontite,!‡ Chrysocolla,! Calamine,!‡ Apophyllite, Thomsonite,! Natrolite,!‡ Mesolite,! Analcite, Chabazite, Stilbite, Deweylite, Prochlorite.

ON BOILING.

E. *Without evolution of Gas.*	F. *With liberation of CO_2.*	G. *With liberation of H_2S.*	H. *With separation of SiO_2.*
Cuprite,! Zincite, Goethite,* Limonite,* Apatite.* Gypsum,*	Hausmannite,† Pyrolusite,† Manganite,† Psilomelane,!† Wad,!† Magnesite,! Siderite,!	Bornite, Jamesonite,* Bournonite,* Boulangerite,	Tephroite,‡ Ilvaite, Phlogopite,* Datolite,!‡ Prehnite,* Heulandite, Serpentine, Bastite,
and those in A.	*and those in B.*	*and those in C.*	*and those in D.*

reference may be made to other solvents, such as water itself, various mineral acids, and saline solutions, their agency in nature

! Completely decomposed or dissolved. * Feebly attacked.
† The CO_2 evolved is derived from the Citric Acid. ‡ Gelatinizes.

is not ignored; nor is any attempt now made to compare their relative efficiency with that of the special agency under discussion. Neither is the important and broad subject of the geological work of "organic matter" included, with reference to its general reducing influence, the development of gases, the accumulation of carbon, etc.

II. Materials Yielding Humus Acids.

§ 3. *Varieties of humus.*—In nature, the complex mixture of organic substances, styled humus, is found under many forms: the *brown* variety, in living vegetation, in the outer bark of many trees, in the excrescences attending unhealthy growth, especially studied in those of the elm, and in the mould and ergot of many grains and grasses, in many fungi, etc., in the dead leaves hanging to trees, the upper and drier layers of the fallen litter and of peat, and the decaying sea-weeds upon the shores: the *black* variety, in a more or less active state of decomposition, in the deeper layers of the soil, of the rotting leaves and wood of the forest, and of the mud, muck, and peat of swamps, bogs, and ponds, in the dung of animals, birds, etc.: in a state of transference, in the waters of springs, mineral-waters, rivers, lakes, and even in rain-water: and in a fossil condition, not only in lignite, brown-coal, and many carbonaceous deposits, but locked up in the hygroscopic water and organic matter of many minerals and especially of many hydrated ores of iron and manganese.

§ 4. *Forest-litter.*—The chemical constitution of the forest-litter of fallen leaves, and of the humus produced by their decay, has been the subject of investigation by several analysts, for agricultural purposes; but these results are of little use for further application, on account both of their limited number and of the common neglect to estimate, in each locality, the influence of the character of the soil. Some of the observations of Krutzsch[2], Ebermayer[3], and Dulk are presented on page 314.

The variations in lime and silica in the above analyses are attributed chiefly to the soil. It is found that the presence of tannin or resinous matter retards decomposition, while that of the alkalies and lime assist it. In Bavarian forests, with the coniferous trees, a period of from three to eight years is necessary for

[2] Chem. Ackersmann, 1866, 158. [3] Landw. Vers. Stat., 1875, XVIII, 62-77, 205.

the formation of humus from the leaf-litter, but with deciduous trees from two to five years are sufficient.[4]

FOREST LITTER. *Nitrogen.*	K^2O	Na^2O	CaO	MgO	Fe^2O^3	P^2O^5	SO^3	SiO^2	Total ash
Beech..... 0.8 to 1.24	2.81	.56	24.49	3.50	1.73	2.98	1.10	18.37	55.9
Oak..... 1.05	3.28	1.28	23.68	3.80	1.03	2.95	1.51	18.83	55.1
Spruce fir..... 1.35	1.61	.56	20.27	2.32	.93	2.14	.70	16.54	45.3
Scotch pine 1.89	1.51	.61	5.82	1.51	.49	1.11	.57	2.12	14.7
HUMUS.									
Beech forest.....	1.53	.26	10.22	2.54	3.97	2.79	1.86	20.03	43.2
Fir forest.....	2.19	.39	23.39	1.79	2.50	4.19	1.76	7.80	44.

§ 5. *Composition of humus.*—The nature of the decomposition which thus takes place is partially represented by the following ultimate analyses[5] of the peat at different depths in a peat-bog of the Nienwalder High-moor of Gutes Jessback, in Holstein.

	Ash	N	C	H	O
Brown peat from the surface,	2.72	.80	57.75	5.43	36.02
Nearly black peat, at a depth of 7 feet,	7.42	2.10	62.02	5.21	30.67
Black peat, at a depth of 14 feet,	9.16	4.05	64.07	5.01	26.87

The above results indicate a gradual downward transference and concentration near the bottom of the bog, both of the more carbonaceous and nitrogenous matters of humus, by loss of water and oxygen, and of most constituents of the mineral matter. The character of the latter is shown in several good analyses of peat and muck (Johnson's Essays on Manures. Cook, Rep. Geol. N. J., 1863, 481, and 1878, 47); but exact determinations of the carbonaceous matters are very rare. A peat from the vicinity of Moscow, Russia, gave Hermann[6] the following percentages: Muck-carbon, nitrolin, and plant-remains, 77.5: humic acid, 17.: humus extract, 4.: ammonia, 0.25: crenic acids, traces: ash, 1.25; in another peat, muck-carbon, etc., 80.: apocrenic acids, 17.: crenic acids, 1.: ash 2. The virgin-soil of the "black earth" (Tschornozem) of the Russian steppes[7] yielded the following per-

[4] Ebermayer, Gesammte Lehre der Waldstein: See Watts Dict., III Suppl., Part I, 823.

[5] Detmer, Landw. Vers. Stat., 1871, 270.

[6] R. Hermann, Erd. Jour. f. pr. Ch., 1842, XXVII, 165.

[7] R. Hermann, *idem*, 1837, XII, 290, and 1842, XXVII, 174.

centages; sand, clay, etc., 89.58: nitrolin, etc., 1.66: humic acid, 1.77: humus extract, 3.10: torfic acid, 1.77: crenic acids, 2.12.

The inorganic matters in peat-moss (Sphagnum), as represented by its ash, amount to 3 to 4 per cent., and in dried peat from about 1 to 25 per cent., averaging in the denser varieties 15 per cent. In the careful investigation by Vohl[8] of the peat of a high moor in the Canton Zürich, containing 0.92 per cent. of ash, he obtained the following results, briefly summarized. The large content of alkalies (20 per cent. of the ash) and of silica (42 per cent.), in the moss, have been mainly carried off into the bog-waters, only 3 or 4 per cent. of each remaining in the peat; the same substances are also drawn up by the later vegetation, and thus occurs upwardly "a transference of these mineral substances from one peat layer to another." Of the remaining constituents, present in small quantity in the moss, there has been a heavy concentration of alumina, ferric oxide, and lime in the peat, and even of phosphoric and sulphuric acids in a less degree.

Many instances have been noted of the occurrence in peat bogs, etc., of layers of pulverulent calcium carbonate, resulting probably from the decomposition of ammonia-lime double salts of the humus acids.[9]

Peat sometimes abounds in pyrite, and the decomposition of this mineral contributes a basic ferric sulphate to the bog ores afterwards produced.[10]

§ 6. *Nitrogen in humus.*—Natural humus (*e. g.*, from peat) is found to contain from 1 to 3 per cent., or more, of nitrogen, and the dry soil of forests from 0.00012 to 0.00087 per cent. of ammonia. The nitrogen-content in peat, which has a very important office, has been attributed to the decomposition of the albuminoid substances of living vegetation, to direct absorption of nitrogen gas from the air by humus, during its oxidation,[11] and of nitric and nitrous acids and ammonia from atmospheric waters,[12] etc. Schultzenstein attributes it to the infusoria, polyps, worms, mollusks, crustaceans, and insects, which live in the peat and soil; but these very animals must have derived their nitrogen from the living plants and humus-remains on which they feed. As

[8] Ann. Ch. Pharm., 1859, CIX, 185. [9] Roth, Allg. u. Ch. Geol., 1879, I, 596.
[10] Roth, *idem*, 598-9. [11] P. P. Dehérain, Compt. rend., 1872, LXXIII, 1352.
[12] P. Bretschneider, Chem. Ackersm., 1871, 187.

Dr. J. H. Gilbert has shown,[13] the evidence in regard to the *source* of the nitrogen is still contradictory and the question must be considered unsettled. But in regard to its *accumulation*, in a form having little tendency to decomposition, an important condition is shown in the enclosure of animal remains, especially the exuviæ of insects, of which certain species swarm in vast numbers under the shelter of swamp vegetation. A recent observer in the western territories reports the superficial layer of a peat-bog to contain a remarkable abundance of the wing-cases of beetles. Prof. S. H. Scudder of Cambridge, Mass., has recently reported a similar occurrence of insect-remains in a partially submerged bed of peat at Nantucket; and one incidental result of the investigations by himself and others, on the insect-fauna of the Carboniferous strata and of carbonaceous shales of other periods, is the increasing evidence of an abundance of insect-life in those ancient marshes, proportionate to the richness of vegetation and depth of marsh-deposits, indicated by the present accumulation of fossil carbon. These facts, and those known in regard to the character of the fauna of the swamps and bogs of the present day, seem to indicate at least that the concentration of nitrogen in a comparatively stable form, yielding a steady supply of that element for the formation of the azotized combinations of the humic acids, has been largely dependent upon the accumulation of the exuviæ of insects within the humus deposits.

Its concentration in the lower layers, noted by Detmer and explained (*loc. cit.*) by the supposition that "the nitrogenous, perhaps leather-like bodies, which are formed, are decomposable with very great difficulty," may be simply due to the survival of such exuviæ in the form of chitin. It has also been suggested that the oolitic structure, in a Belgian iron-stone of Devonian age, has been due to the eggs of aquatic insects which the iron-ochre has incrusted, like the same structure in the recent oolitic limestone of the great lakes of Mexico.[14]

The important chemical agencies and results, afterwards described, appear therefore to depend for their genesis, at least largely, upon this relationship to the insect-world: *e. g.*, the iron-ores of the Archæan strata, the extensive iron-stone layers associated with the coal, and the profound chemical erosion, which

[13] Am. J. Sci., 1877, (3), XIII, 20, 99, 181.
[14] T. L. Phipson, Compt. rend., 1861, LII, 975.

preceded and rendered possible the enormous denudation of northern areas during the Glacial period.

§ 7. *Distribution of humus.*—A brief reference may also be made to the geographical distribution of the humus-layer. On land, even in its thinnest development, as under cryptogamous growth upon rocks, it seems endued with special activity for corrosion. In ordinary soils its wide extension is well known, but there are special varieties which seem to be exceptionally rich, *e. g.*, the "Regur" or rich cotton-soil of Hindostan,[15] the productive thick humus of the American prairies and of the Southern steppes of Wallachia, Moldavia, etc., especially the "Tchornozem" or "black earth" of the steppes of southern Russia.[16] The latter occupies the centre of a trough 200 millions of acres in extent. It contains 6 to 10 per cent. of organic matter, consisting of humic, crenic, apocrenic acids, etc., and 2.45 per cent. of nitrogen, by the analysis of Payen. In the depressions of the surface, near the water-courses, lakes, and seas, occur still richer accumulations of humus in the form of peat-bogs, swamps, and salt-marshes, which even girdle the continents; and there are many reasons to believe that the very bed of the ocean, in its profoundest depths, supports deposits in which humus-like products of decomposition play their part.

An attempt has been made in the Plate to give a general view of the superficial extent of chemical corrosion and decomposition now in progress by these agencies throughout the world. The dark areas represent, with some exaggeration of effect, the richest deposits of humus, in which the chemical action is presumably most active, *e. g.*, rich soils, layers of humus upon the flanks of mountain ranges, fresh-water swamps near lakes and along the courses of rivers, and salt-marshes along oceanic shores. The lighter shading represents the inferior degree of chemical action exerted by ordinary soils, rock-surfaces covered with cryptogameæ, etc. The areas free from shading are those in which there is little vegetable growth except during short seasons of heavy rains or summer warmth, *e. g.*, arid deserts, the summits of high mountains, tracts of sandy dunes, and the ice-capped Arctic and Antarctic regions. The *Tundra* belt, along the northern border of

[15] Capt. Newbold, Rec. of Roy. Soc.

[16] R. I. Murchison, Russia and the Ural Mts., Geol., 1845, I, 557 *et seq.*, and Trans. Roy Agric. Soc., III, 1; also F. Schmidt, Zeits. d. D. geol. Gesells., 1877, XXIX, 830, 835; and R. Hermann, *loc. cit.*

the continents, is an area made up of frozen mossy swamps and rocky hummocks covered with lichens, mosses, and saxifrages; it must comprise a considerable amount of humus of an acid character. A comparison of this map with the published geological charts, which show the regions covered by coal-basins, affords some conclusions of interest, especially confirming the shifting position of the areas of extreme erosion at different periods.

III. Acids Existing in Humus.

The organic acids, resulting from the decomposition of humus, appear to be numerous and very unstable; their investigation has as yet been only begun, and even the results so far attained are vitiated, for our present purpose, by the general absence of discrimination between the characteristics and reactions existing in nature, and those produced by the artificial conditions of laboratory investigation. Having eliminated, therefore, all observations which appear to be exclusively artificial, and all which have no apparent geological bearing, I will now briefly describe the particular acids which probably are actually diffused through humus and its natural solutions. Of course but very few of these acids are actually present in most deposits of humus; the larger number are evanescent in their duration, but *contribute* to the acid character of the organic salts in all natural humus.

§ 8. *Inert substances.*—Two constituents of humus exist and may first be mentioned, which are insoluble in water, acids, and alkalies, which are amorphous, neutral, inert, and yet serve, by oxidation of their abundant material, to furnish a continual supply of the soluble acids, and, by their absorptive powers, a supply of nitrogen to form their nitrogenous combinations and ammoniacal salts. *Nitrolin*, the principal constituent of rotten wood, is of a brown color, containing 56.13 per cent. of carbon and 4.00 to 12.30 per cent. of nitrogen. *Humin*, the principal constituent of the true humus, is of a black color, but is too closely intermixed with woody-fibre and nitrolin to permit its accurate analysis. Hermann also finds *anitrohumin* in peat. Mulder studied humin (and humic acid) as obtained from the *black* compact peat of the Haarlem sea; but he also distinguished *ulmine* (and ulmic acid), as occurring in rotten wood and in the *light-brown* Frisian peat. To the latter he assigns the formula, $C^{20}\ H^{16}\ 0^{7}$ (or, $C^{12}\ H^{9.6}\ O^{4.2}$,

as H. Wurtz[17] suggests, making it isologous with cellulose, $C^{12}H^{20}O^{10}$); but it is probably a mixture of two or more compounds. He obtained a substance, termed humus or humine ($C^{12}H^{9}O^{4.5}$, Wurtz), as the product of oxidation of ulmine, with separation of water; and he suggested that this action is in constant progress in the mud upon the bottom of lakes, etc.

A collation of the most reliable investigations yet made has furnished the following summary of the chief organic acids in humus.

§ 9. *Humic Acid.*—This is found in decayed wood, especially that of the elm and beech, and in peat, vegetable mould, etc. A large proportion (ulmic acid?) is said to occur in the prairie soil of this country.[18]

Percentage Composition.

	C	H	O
Humic Acid (with 3 aq.)	64.	4.	32.
" " from peat (Detmer[19])	59.74	4.48	35.78
" " " soil (Bretschneider[20])	60.39	4.50	35.03
Ulmic Acid from brown peat (Mulder[21])	62.62	4.62	32.76
" " (with 1 aq.)	67.1	4.2	28.7

Stein concludes that the ulmic acid and ulmine of Mulder are isomeric, with the formula $C^{24}H^{18}O^{9}$, and Detmer considers the ulmic acid identical with humic acid and produced by drying at too high a temperature. The generally accepted results of the more recent analysts, such as Detmer and Bretschneider, render it probable that nitrogen is unessential to the constitution of this acid, and the analyses containing it are therefore excluded. The formulas ascribed to the acid are as follows:

		(H. Wurtz.)
Humic Acid (Detmer)	$C^{60}H^{54}O^{27}$	
" " (Mulder)	$C^{20}H^{12}O^{6}$	
Geic " (")	$C^{20}H^{12}O^{7}$	$C^{12}H^{7.2}O^{4.2}$
Ulmic " (")	$C^{20}H^{14}O^{6}$	$C^{12}H^{7.4}O^{3.6}$
	or perhaps	$C^{24}H^{18}O^{8}$

Humic acid possesses a strictly colloid nature, and, as found

[17] Johnson's Cyclopedia, article "Humus."
[18] L. Lesquereux, Geol. of Ill., 1866, I, 252.
[19] Landw. Vers. Stat., 1871, XIV, 260.
[20] Chem. Ackers., 1871, 287.
[21] Bull. de Sci. phys. et nat. de Neerl., 1840, 1—102: abstract in Ann. der Chem., 1840, XXXVI, 243.

by the direct experiments of Detmer,[22] is not absorbed by the rootlets of plants, though its oxidation-products (*e. g.*, crenic acid) appear to be taken up.

While moist it is black, has an acid taste and reddens blue litmus-paper, absorbs oxygen and yields carbon dioxide by natural decomposition; it dissolves in 8333 parts of water at 6°C., and in 625 parts at 100°C. Its solubility is diminished by the presence of salts, and it is insoluble in water free from nitrogen or air.[23] After drying at 120°C., it dissolves in 13784 parts of water at 15°C., and, after perfect drying, at high temperatures, becomes insoluble.

It is far more soluble in aqueous solutions of the alkalies. It expels carbon dioxide from metallic carbonates, but can also be expelled by that acid from all combinations. All its salts are black. Its alkaline salts are easily soluble, but those of the alkaline earths and metallic oxides are not soluble or only with very great difficulty. Yet its insoluble salts are soluble in aqueous alkalies, especially in ammonia and its carbonate, and partly also in aqueous alkaline carbonates. Humic acid does not combine with silica, unless ammonia be present.

It has also the colloidal property of gluing together vegetable earths, such as the siliceous sands of the Landes near Bordeaux, into a layer impervious to water (called "alios")[24]; this has also been proved by direct experiment.[25]

Ammonium humate (C^{60} H^{48} $(NH^4)^6$ O^{27}, Detmer) dissolves in 22 parts of water, and exists in peat. According to Mulder, the formulas are as follows:

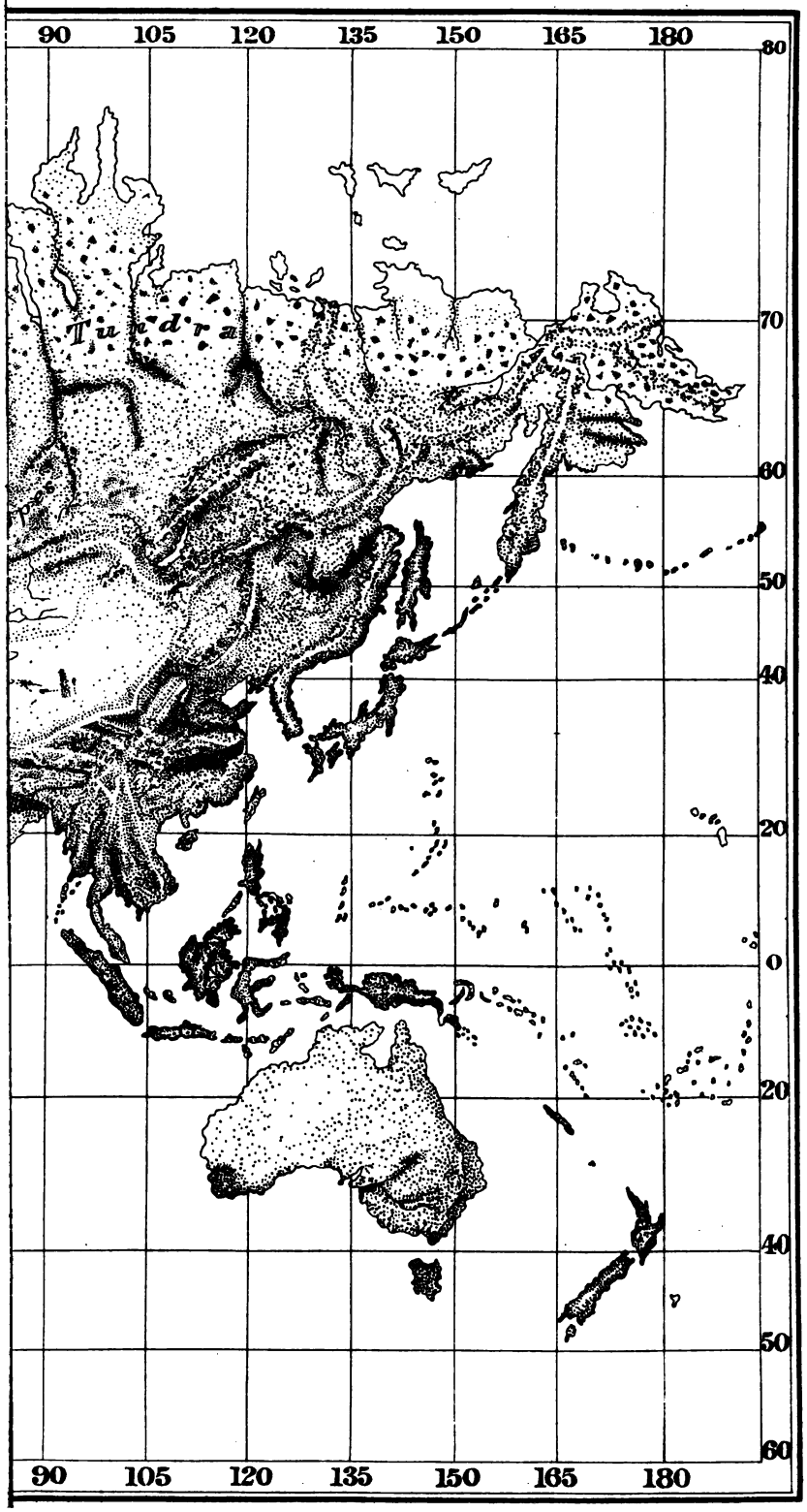
Humate, C^{20} H^{12} O^6, NH^3, + 4 or 5 aq., containing 60.1 per ct. C.
Ulmate, C^{20} H^{14} O^6, NH^3 + 3 aq., containing 61.2 per ct. C.

Sodium and potassium humates are soluble, as well as their double salts with ammonia.

Calcium humate dissolves in 3125 parts of water, and there is also a soluble double salt with ammonia (C^{90} H^{46} Ca^3 $(NH^4)^2$ O^{27}).

Magnesium humate dissolves pretty easily in water.

[22] Landw. Vers. Stat., 1872, XV, 284–286.
[23] E. Simon, Landw. Vers. Stat., 1875, XVIII, 452–472.
[24] Fauré, Ann. de Ch. et Phys., 1853, (3), XXXIX. 85.
[25] Th. Schloesing, Ann. de Ch. et Phys., 1874, (5), II, 532.


90
105
120
135
150
165
180
80
70
60
50
40
20
0
20
40
50
60
Tundra

Ferric humate dissolves in 5000 parts of water at 19° C. (in 2300 parts according to Bischof),[26] and its double salt with ammonia (C^{60} H^{46} $(Fe^2)^{VI}$ $(NH^4)^2$ O^{27}) is also soluble.

Manganic humate also forms a soluble double salt with ammonia.

An observation of great importance is that all humous acids absorb nitrogen from the air,[27] and that humic acid, mixed with solution of potassa, absorbs from the air 7.2 per cent. of nitrogen, and converts it into ammonia during oxidation; also the humus from old wood, mixed with solution of potassa, absorbs 3.6 per cent. of nitrogen.[28] On this ground the theory has been advanced that humic acid acts as the ammonia-provider in soils. Nitric acid is found to convert both ulmic and humic acids into formic and oxalic acids associated with ammonium-apocrenate.

Mulder finds that ulmic and humic acids "do not exist to much extent in the free state, except in bogs and morasses." In the soil they assume acid characters only by reaction with carbonates, and then become salts, *i. e.*, enter into combination. Other similar constituents of humus, soluble in water, of less certain character and determined composition, are the following:

Humous extract (C^{16} H^{32} O^7 N^2 (?), Hermann) occurs in tilled soil, peat, and rotten wood. It is brown and easily soluble in water, forms a sparingly soluble compound with lime, but presents mostly neutral properties.

Mudesous acid (C^{12} H^{10} O^8),[29] obtained, in combination with alumina, from pigotite, and probably derived from the decomposition of humus on moorlands.

Humous acid, obtained from Russian "black earth."

Azulmic acid[30] (C^4 H^4 N^4 O^2)[31] and *fumic acid*[32] obtained from rotten dung: the latter however, according to Mulder, being impure ammonium-humate.

Carbo-ulmic acid (C^{40} H^{36} O^{16}) and *Carbo-humic acid*, obtained from lignite.[33] These have yielded the following percentage composition:

[26] G. Bischof, Chem. and Phys. Geol., I, 166.
[27] R. Hermann, Erd. Jour. f. pr. Ch., 1841, XXII, 69.
[28] Déhérain, Compt. rend., 1873, LXXIII, 1352.
[29] J. F. W. Johnston, Phil. Mag., 1840, XVII, 382.
[30] Braconnot, N. Ann. Ch. Phys., 12, 212.
[31] Pelouze and Richardson, Ann. Ch. Pharm., 1838, XXVI, 63.
[32] P. Thenard, Compt. rend., 1859, XLIX, 289.
[33] Herz, N. Repert, 10, 496.

	C	H	O
Carbo-ulmic acid	62.36	4.79	32.87
Carbo-humic acid	64.59	5.15	30.26

Ligno-humic acid (C^{30} H^{60} O^{12} N^6, Hermann), obtained from brown rotten wood, is somewhat soluble in water to a yellow solution, but is precipitated by mineral acids.

Anitro-humic acid (C^{20} H^{40} O^{10}, Hermann), obtained from peat, etc.

We have next to consider the products of higher oxidation of the feebly soluble acids thus far described. The most important are two, crenic and apocrenic, first identified by Berzelius, whose far greater solubility has resulted in their extensive distribution: so that they have been artificially separated for investigation, not only from peat and soils, but also from their widely diffused solutions in combination with iron and other bases.[34]

I have separated both these acids, in considerable quantity, from the peat which occurs at the southern end of Ballston Lake, in Saratoga County, N. Y.

§ 10. *Crenic acid.*— (C^{24} H^{24} O^{16} + 3 H^2 O, or C^{24} H^{30} O^{19}, Wurtz.) [Quellsaüre, Humusquellsaüre, Krensaüre, Brunnensaüre, etc.]

This occurs in the waters of probably all springs, rivers, lakes, etc., and in rain-water:[35] in rotten wood, peat, and tilled soil: and in bog ore, ochre, etc. It is of a pale yellow color and transparent, becoming yellow and opaque on drying; turns dark by exposure to the air, absorbs oxygen, and leaves a brown residue of apocrenic acid; is easily soluble in water, tastes sharply acid, reddens litmus, is styptic in strong solution, and forms white or light-colored neutral and acid salts. Salts of the alkalies are easily soluble, but less so than the pure acid, and are generally diffused; ammonium-crenate has been found in some iron ores.

Calcium-crenate is a neutral pale yellow salt, soluble in much water; a basic salt also exists, containing 20.59 per cent. of lime. Magnesium-crenate is easily soluble. Aluminum-crenate is a yellow salt, insoluble in water; with a larger proportion of acid, a soluble salt is formed, which, on addition of ammonia, is not precipitated but remains soluble. Ferrous crenate is soluble in acids; also in water, to a limpid and styptic solution, yielding

[34] Gmelin's Handbook of Chem., XVII, 466—475.
[35] Salm Horstmar, Pogg. Ann., 1841, LIV, 254.

the usual reactions of a ferrous salt; but absorbs oxygen with extreme avidity, both from the air and from solid bodies, thus acting as a strong reducing agent, and passes into ferric crenate.

Ferric crenate is an earthy salt of a dirty-white color, or an ochreous brown flocculent deposit, insoluble in water (moderately soluble, according to Mulder and Bischof) and in acids. It dissolves completely in ammonia, so that, as Bischof remarks,[36] if there are decaying nitrogenous substances present, which evolve ammonia, *this salt may also be dissolved.* This apparently forgotten observation of Bischof may be of much geological importance, since it shows, contrary to the usual statements (LeConte,[37] Hunt,[38] etc.) that ferric crenate (and probably humate and apocrenate) *can* be dissolved, even without reduction, in ammoniacal solutions. On evaporation of the latter, they leave a reddish-yellow residue: from this residue water separates a soluble neutral double salt, leaving behind an insoluble basic salt. Manganese-crenate is moderately soluble (Mulder). Aluminum-crenate is insoluble (Mulder). The insoluble salts of both crenic and apocrenic acids are decomposed by and soluble in excess of solution of the alkaline salts. Silicic acid, precipitated from a liquid containing crenic acid, takes up a portion of the latter.

Hermann finds two groups of acids, the *crenic* and *oxycrenic* acids, occurring in nature, viz:

Humo-crenic acid (C^{18} H^{36} O^{9} N^{4}), found in the "black earth:"

Torfo-crenic acid (C^{15} H^{48} O^{12} N^{4}), found in peat, "black earth," and mineral-waters:

Torf-oxycrenic acid (C^{12} H^{12} O^{4} N^{4}), found in a mineral-water.

§ 11. *Apocrenic acid.*—(C^{24} H^{12} O^{12} $+H^{2}$ O, or C^{24} H^{14} O^{13}, H. Wurtz.) (Quellsatzsaüre.) This occurs in the water of springs and rivers, in tilled soil, peat, decaying wood, and bog-ores. It is of a black-brown color, reddens litmus, has a styptic taste, and dissolves with brown color in water: some modifications are sparingly soluble. Crenic and apocrenic acids may be precipitated together by a mineral acid, out of an alkaline solution, as an amorphous light-brown mixture, very hygroscopic, with an acid reaction sufficiently strong to dissolve in the cold recently precipitated ferrous carbonate.[39]

The salts of this acid are amorphous, black-brown, easily

[36] Op. cit., I, 166. [37] El. of Geol., 1879, 136. [38] Essays, 227.
[39] C. Boutigny, Compt. rend., 1871, LXXIII, 247.

soluble in water but generally less so than the crenates, both being generally more soluble than the corresponding humates. Ammonium-apocrenate is freely soluble in water, with an acid reaction. Potassium and sodium-apocrenates are black, neutral, and freely soluble in water, with brown color. Calcium-apocrenate is black-brown, gradually dissolves in water: there is also a basic salt, insoluble in water. Magnesium-apocrenate resembles that of lime. Two aluminum-apocrenates probably exist, in which the proportion of alumina is small; the one is a soluble salt, and the other, according to Mulder, insoluble. Neutral ferrous apocrenate is soluble, and is converted into basic ferric salt by exposure to the air. Basic ferrous apocrenate is black, insoluble, turning brown in the air. Neutral ferric apocrenate is soluble, and the basic salt insoluble. Manganese-apocrenate is moderately soluble. In regard to these two acids, Mulder observes (*op. cit.*, p. 350) that they exist in the soil nearly always as double salts of lime, iron, etc., with ammonia: that in the loose dry earth, apocrenic acid is formed by oxidation, and, in every soil, after rain, crenic acid by reduction, "so that the action or effects of these substances are alternately manifested."

Hermann divides his group of *apocrenic acids*, as follows: *Torfic acid* (C^{20} H^{32} O^{6} N^{4}), found in peat, soil, and brown coal. Its alkaline salts are soluble, dark-brown, and absorb oxygen; its other salts are mostly insoluble in water.

Arvic acid (C^{30} H^{48} O^{6} N^{12}), extracted from tilled soil.

Porla-apocrenic, from the Porla-water.

Anitro-apocrenic acid (C^{20} H^{32} O^{8}), obtained from peat.

§ 12. *Silico-azo-humic acids.*—The essential combination of silica with certain black acids of the soil was long ago remarked by Verdeil and Rislher; and A. Vogel has pointed out that "the assimilation of silica by a plant depends greatly on the amount of humus present in the soil." The existence of four azo-humic acids has been claimed by P. Thenard.[40] He believes that acids of this series "form spontaneously in the soil, at the expense of the humic acid, the ammonia of rain-water, nitrogen of the air, and of the silica preëxisting in the soil." He discovers that these acids dissolve silica in proportion to the nitrogen they contain, *i. e.*, from 7.5 to 24 per cent.; while with simple humic acids only 0.8 per cent. of silica could be experimentally dissolved, and

[40] Compt. rend., 1870, LXX, 1412.

even in these cases there was doubt of their purity. He further suspects that these organo-silicated combinations may pass into the organic combinations of Friedel,[41] silico-propionic acid, etc., in which silicon plays the part of carbon. Vogel finds that Thenard's compounds are soluble in very dilute alkalies, from which solution they can be separated unchanged.[42]

The solvency of silica in ammonium-crenate, and also in two weak acids, acetic and carbonic, has been shown (C. J. B. Karsten, Pogg. Ann. d. Ph. u. d. Ch., 1826, VI, 359), and the efficiency of others in the same direction does not therefore appear anomalous. It might be anticipated from the existence of a group of such powerful solvents of silica, occurring in great abundance and general distribution in nature, and freely soluble in atmospheric waters, that they must have exerted a decided influence in the decomposition and alteration of porous strata, especially above the water-level; and, in proof of this action, many instances will be given beyond. While the exact character of these acids has not yet (Mar., 1880) been reported, I shall not hesitate to use the name "silico-azo-humic acids," merely, for the present, as a convenient term to distinguish the strong organic solvents of silica which undoubtedly exist in layers of humus.

§ 13. *Acids derived from vegetation, etc.*—In addition to the agency of these products of eremacausis, there is evidence, as Bolton suggests, of the "silent work of a higher class of organic acids" going on in the humus deposits. *Oxalic*, *malic*, *fumaric*, and an enormous number of acids, and their acid-salts with the alkaline metals and earths, are contributed, at least temporarily, by the leaves, stems, etc., of most plants, many of which are rich in raphides made up of minute crystals of those acids or their salts. The bark and excrescences of many shrubs and trees contribute *tannic* and *gallic* acids to the soil. "Falling fruits give it *citric*, *malic*, and *tartaric* acids," which however, in contact with decaying albuminoids, are partially converted into acetic acid, and rapidly and entirely into carbon dioxide.[43] Young roots, especially the finest fibrils, of living plants, contain an acid or acid-salt, which manifests a strong acid reaction to litmus paper.[44] The ground-

[41] Bull. Soc. Chim., 1863, V, 174, 238; Compt. rend., 1870, LXX, 1407.
[42] N. Repert. Pharm., 1871, XX, 143–146.
[43] S. W. Johnson, How Crops Feed, 222.
[44] Zöller, Vs. St., 1862, V, 45.

pine (*Lycopodium complanatum*) contains malic acid, and its ashes 38 per cent. of alumina;[45] its rootlets also exhibit an acid reaction, probably due, in part at least, to the presence of acid aluminum-malate.[46]

"*Formic*, *propionic*, *acetic* and *butyric acids*, or rather their salts, have been detected, by Jongbloed and others, in garden-earth. The latter are common products of fermentation, a process that goes on in the juices of plants that have become a part of the soil."[47] The acids produced by the fermentation of bodies of the cellulose group are *lactic*, *butyric* and *acetic*, and these may possibly be sometimes present.[48] All these acids can scarcely exist, except temporarily and in very minute quantities, in the soil.

Uric acid ($C^5 H^4 N^4 O^3$), *Hippuric acid* ($C^9 H^9 N O^6$), and salts of acids of still more complex character are continually added by the dung of animals, birds, reptiles, and annelids. Recent observers[49] have called attention to the important office of the casts of the ordinary earth-worm (*Lumbricus terrestris*) in the soil layer, and also of the work of ants in covering rocks and in the alteration of soils. If salts of uric and formic acids have not been introduced by these means, at least a strong influence for the aeration and oxidation of humus has been exerted by these agents.

In the lichens the common acids are *oxalic* and *usnic*, but a long series of others have been detected. *Fumaric* and *lichenstearic acids* are present in many agarics; and *polyporic acid*[50] occurs in fungi upon decaying oaks, and, although itself insoluble in water, is found to unite with ammonia and the fixed alkalies in salts which are easily soluble. It has been pointed out that "the decay of forest litter is to a great extent brought about by the agency of fungi;"[51] and it may be inferred that even the more minute species both of fungi and lichens contain, or contribute during their

[45] Salm Horstmar, Jour. f. Prakt. Chem., 1847, XL, 304.

[46] Ritthausen, *idem*, 1851, LIII, 420.

[47] Johnson, *op. cit.*, 222.

[48] Einhof. and v. Pontin; also R. Hermann, Erd. Jour. f. pr. Ch., 1837, XL, 280-281.

[49] White, Nat. Hist. of Selbourne, I, 14, 279; Knapp, Jour. of a Nat., 4th ed., 343; C. Darwin, "on formation of mould," Trans. Geol. Soc., 1840, (2), V, 505, *et seq.*; G. H. Kinahan, Geol. Mag., 1869, VI, 114, 263, 348; Prof. Paley, Hardw. Sci. Goss., 1878, XIV, 121, 154; M. Hensen, Nature, 1877, XVII (Zeits. f. wiss. Zool.).

[50] C. Stahlschmidt, Lieb. Ann. d. Ch., 1878, CLXXXVII, 177.

[51] Watt's Dict., III, Suppl., 823.

decay, supplies of additional organic acids, to be diffused, at least temporarily, through the humus. Overripe fruits are at once attacked, even upon the trees, by lichens and fungi, and, after they are fallen, become thoroughly permeated by these organisms and centres for their dissemination.

Mellitic acid (C^{12} H^6 O^{12}), found in the mellite of lignite-beds, and *succinic acid* (C^4 H^6 O^4), which is found ready formed in amber, etc., and is even yielded by the natural fermentation of malic, fumaric, and other acids, may here be mentioned. There is also a group of acid hydro-carbons, of uncertain character and composition, which have been detected by Williamson, Brückner, etc., in peat-bogs and brown-coal, viz., *georetic*, *geoceric*, *retinic*, *georetinic*, and *butyro-limnodic* acids.[52]

§ 14. *Acids from the atmosphere.*—It is certain also that the ceaseless and varied chemical reactions, which prevail among the constituents of the atmosphere, must yield continual contributions to the humus-layer, not only of carbon dioxide, but also of peroxide of hydrogen, of ozonized aqueous solutions,[53] and frequent supplies of other acids.

Nitric and *nitrous acids*, which meteoric waters contain, must be added in appreciable amount, chiefly in combination with ammonia, especially during summer-storms.[54] Nitrites are found in all arable soils,[55] being especially stored up in clays: Chabrier estimates that a hectare of arable ground, to the depth of 30 cm., receives annually 3.75 kgms. of nitrous acid.[56] The existence and permanence of these acids in deposits rich in humus must probably be ephemeral; in fact nitrous acid is found by Chabrier to pass rapidly into nitric acid, while Kuhlman believes that they are both reduced almost instantaneously to ammonia. Nevertheless, even their temporary action may be of some moment in this connection, as tending to the conversion of humus into ammonium-apocrenate and organic acids of the higher oxidation: such as formic and oxalic acids, as found by laboratory experiment. *Hydrochloric acid*[57] is also found diffused, in minute quantity, in the air above salt marshes.

[52] Gmelin's Handbook, XVII, 444, etc. Dana, Syst. of Min., 747, etc.
[53] R. Leeds, Ann. N. Y. Acad. Sci., 1879, I; D. ch. Gesells., 1879, XII, 183.
[54] Sometimes producing an acid rain, Ducrès, Jour. de Pharm., 1845, April.
[55] Ch. Chabrier, Ann. de Ch. et Phys., 1871, (4), XXIII, 161.
[56] Chabrier, Compt. rend., 1871, LXXIII, 485.
[57] S. W. Johnson, How Crops Feed, 1877, 93.

§ 15. *Carbon dioxide.*—The list of organic acids of humus may be closed by *carbon dioxide*, probably the most important of all, and the final and stable product of the decomposition of all the rest. Its nature and that of its important work in chemical geology have been the subject of extensive investigation and are too well known to need any review here. In the humus layer itself, it is derived in part from the atmosphere, and in part from the decomposition of the humus, especially in its superficial layer. Its abundance there is indicated, according to the analyses of Boussingault and Lewy,[58] by the following figures, representing the number of cubic feet of carbon dioxide contained in a layer fourteen inches deep over an acre of soil.

Ordinary atmosphere . . .	12	cubic feet.
Surface soil of forest . . .	57	" "
Sandy subsoil of forest . . .	14	" "
Loamy " " " . . .	28	" "

However, it by no means follows that the solution of inorganic matter, even in soils, must be brought about by this acid: since, as Johnson notices,[59] it has been found that, even in soils rich in organic matter, the water contained only two per cent. of carbon dioxide, instead of one hundred per cent. or its own bulk, its normal solvent power at 60° F.[60] By a known law, the presence of other diffused gases has in this case hindered its solution. In his two brief but interesting papers[61] on the behavior of humus-materials toward minerals, and influence upon their solubility and alteration, Senft has pronounced decidedly that there must be other fluids, besides the solution of carbon dioxide, which produce the alteration of minerals, the decomposition of species which are insoluble in pure and carbonated waters, and even their re-deposit in an unaltered condition. The fluids of chief efficiency he believes to be solutions of the alkaline (especially ammoniacal) salts of ulmic, humic, crenic and apocrenic acids.

For these among other reasons, it appears that, in the infiltrating solutions which are carrying on the chemical alteration within the underlying strata, an undue prominence has in very many

[58] Mém. de Chim. agric., 369.

[59] S. W. Johnson, How Crops feed, 221.

[60] De Saussure, Rech. chim. sur la Vegét., 168. Also Van den Broek, Ann. d. Ch. u. Ph., 115, 87.

[61] Zeits. d. D. geol. Gesells., 1871, XXIII, 665, and 1874, XXVI, 954.

cases been assigned to the action of carbon dioxide, in comparison with or in entire disregard of the work of its associates. Senft has explained (*loc. cit.*) that the solutions of the other humus-acids are readily converted by a natural decomposition, constantly in progress, into solutions of carbon dioxide. This fact appears to me to show another important office served by the former, in *acting as carriers of carbon* to lower depths. There, by gradual oxidation, they yield a supply of carbon dioxide for chemical work, where perhaps thermal conditions might have prevented its entrance in ordinary carbonated solutions. Illustrations of this fact may be found in the thermal and therefore non-aerated water of St. Allyre, near Clermont, France, which contains 0.0046 per cent. of crenic and apocrenic acids combined with iron, and even 5 per cent. in its deposit of travertin: also in the thermal waters of Luxeuil, France, which deposit a travertin containing 1.02 per cent. of crenic acid.[62]

IV. Conditions of Existence.

§ 16. *Genesis of the humus acids.*—The conditions which affect the genesis of the humus-acids have yet to be carefully studied. It is sufficient here to remark that they belong chiefly to three classes. First, the *materials* supplied for decomposition must depend upon the flora of the locality, which may vary with latitude, elevation above the surface, and local conditions of climate. Secondly, the *nature of the decomposition* will be chiefly affected by climate, exposure to sunlight, and amount of aeration. For example, it may be expected that in a comparatively warm, moist climate, with an atmosphere rich in ozone, and a layer of humus resting upon a porous stratum, the most rapid and highest oxidation will be carried on, and yield the largest product of the most complex and freely soluble acids; while, on the other hand, in a dense swamp or heavy forest, in a cold climate, a large part of the humus will remain insoluble, and a *relatively* small proportion of certain acids will be formed. Lastly, the *transference* and destination of the products of decomposition will chiefly depend upon the rainfall, as the agent of transport; upon the temperature, as affecting both the movement of meteoric waters and the permeability of the surface; upon the topography, as determining the rapidity and direction of the flow of sub-aërial streams; and upon

[62] Roth, *op. cit.*, I, 583, 590.

the lithological character of the superficial strata, as conditioning the subterranean absorption of the solutions from above.

§ 17. *Duration of the humus acids.*—The duration of these acids, both in existence and in chemical action, is also affected by a great variety of conditions similar to those already mentioned. Except where vast periods of time have been allowed, no extensive or deep-seated effect may be assigned to their action, in geological work, unless the circumstances have been such as to afford them in large and constant supply, in dissolved and most erosive form, and in favorable application to soluble and porous masses of rock. But on account of their extreme instability, through their rapidity and ultimate certainty of complete oxidation, it must always occur that, however great the work they have accomplished, *the acids themselves have with rare exceptions completely disappeared.* A portion of the carbon remains locked up in the beds of coal and graphite; and a still less amount, now and then, as a carbonate; or a trace of azo-humic acid may be represented in the "empyreumatic odor" of the distillate of some mineral; or even such acids as humic and crenic may remain imprisoned in the tenacious hold of deposits of ferric hydrate or of manganese oxides, of recent age or close subterranean envelopment. But the greater portion of the substance of these erosive agents has returned to the atmosphere; and it is for this reason, I think, that their geological work has been underrated, or attributed, to an excessive extent, to a single member of the group — carbon dioxide.

V. Natural Solutions.

§ 18. *Various investigations.*—The solutions occurring in nature which serve as the agents of transference of the acids of humus to their various fields of chemical action, the identity of the acids in each menstruum, their amount, the nature of their combinations with bases, and the alterations they undergo, have already been the subject of careful enquiry by many analysts. The waters of bogs and peats have been examined by Liebig and Vohl; those of springs and mineral waters, by Lersch, Kersten, T. S. Hunt, C. F. Chandler, etc.; and those of rivers by Ste. Claire Deville, Hunt, Peligot and others.

From the works of Johnson, Liebig, etc., the following table has been compiled, showing the *percentage proportion of silica* in

the total amount of solid matters obtained, by various analysts, in solutions of natural products, viz.: in aqueous solutions of 22 soils (Krocker, Way, Zöller, E. Wolf, Grouven, etc.): in a solution of decaying moss (H. Vohl): in a solution of saltmeadow muck (Harms): in a bog-water at Munich (Liebig): and in an artificial solution of peat (R. Hoffman).

Soluble Silica.

Soils, average	5 : trace to 28.	Percentage in residue of water-solution.
Decaying moss	17.	
Saltmeadow muck	4.	
Bog water	3.	
Peat	trace.	

The connection of the solvency of silica with the dissolved humus matters has been generally recognized; but these figures suggest that the solution of silica in natural waters is effected, not so much by the constituents of black humus as by those of the brown or ulmine, *i. e.*, by the vegetable matters in a state of active decay and rich in nitrogen, in *a thin upper layer* of soils, forest-litter and peat-bogs, which is leached out by waters flowing over the surface. Bouis found a large amount of silica in the albuminoids of mineral waters, even 80 per cent. in *glairine*, which contains less nitrogen than the other organic matters, and is not a true albuminoid. Such a substance may generally act as the medium for the solution of silica, afterwards transferring it to the products of higher oxidation, such as the azohumic, crenic and other acids.

A partial confirmation of this theory appears to be furnished by the extraordinary richness of the waters of the marshes and of the subsoil of the Landes, near Bordeaux,[63] both in albuminoid organic matter (0.041 to 0.186 gramme to the litre of water) and in silica and oxide of iron (0.016). The district is underlaid by an impenetrable layer (called "alios") of siliceous sand aggregated by vegetable matter. The amount of albuminoid matter decreases in the subsoil waters with their depth below the surface of the soil: those resting upon a layer of "alios" at a depth of 1 or 2 metres ("eau aliosique albumineuse") containing 0.186, while

[63] Fauré, Ann. de Ch. et Phys., 1853, (3), XXXIX, 85.

those at a depth of 3 to 4 metres ("eau aliosique") contain only 0.105 gramme.

§ 19. *Humus acids in river-waters.*—In rivers it has been pointed out by Hunt that an intimate connection exists between a hydrographical basin abounding in humus, and a large content of dissolved silica in the river-water;[64] and he illustrates the statement by a reference to two rivers (italicized below). The subject needs a more extended illustration here, to suggest the amount of transference of silica by organic acids to the coast. The following table has been compiled therefore from the best published analyses, by Deville, Frankland, Maumene, Peligot, Chandler, H. Wurtz, etc. Deville found silica to be present in all the waters analyzed, as well as organic matters, often containing crenic and apocrenic acids; he refers the color of the waters, blue, green, or yellow, to the amount of their content of organic matters, but not the solution of silica: this he considers as probably effected by a little alkali, either free or as carbonate.[65]

The figures below show the percentage proportion of silica in the total amount of *inorganic* solid matters in the waters of each river. Except in the case of the Thames, where a full series is presented, and that of the Nile, where the sample was taken at a great distance (2 hours) below, no analytical results have been admitted which have been obtained from samples taken below large cities: since the influence of sewage, the waste products of manufactories, etc., would have vitiated the application of such data to our present purpose. The *absolute* amount of silica conveyed is of course by no means represented by these figures.

Silica Dissolved in River-waters.

Exe (Exeter)	*trace.*	Mohawk (Schenectady)	5
Rhine (Cologne, 1870)	0.2	Thames (Barnes)	5
Cetinje (Dalmatia)	0.6	Severn (Wales)	5
Danube (Buda Pesth)	0.8	Rhine (Bonn)	5.2
Arve	0.9	Hudson (Albany)	5.4
Vesle (Chateau d' Eau)	0.9	Thames (Lambeth)	5.7
Aar (Berne)	1.2	Rhine (Arnheim)	6
Rhine (Basle)	1.3	Dee (Aberdeen)	6.3
Suippe (Rheims)	1.3	Doubs (Riotte)	6.9
Thames (Twickenham)	1.4	Maas (Bocholt)	8.9
Dwina (Archangel)	1.7	Maas (Hocbt)	9
Maas (Grave)	2	Passaic (Belleville)	9.2
Schuylkill (Philadelphia)	2	Seine (Berry)	9.6

[64] *Op. cit.*, 1878, 126, 150.

[65] H. Ste. C. Deville, Ann. de Ch. et Ph., 1848, (3), XXIII, 32-38.

Main (Offenbach)	2	Maas (Pierre Bleue)	10
Isère (Grenoble)	2.1	Croton	10
Thames (Kew)	2.3	Don (Aberdeen)	10.6
Seine (Paris)	2.7	Delaware (Trenton)	14.9
Clyde (Glasgow)	3	Passaic (Newark)	15
Marne	3.3	Nile (below Cairo)	16.1
Thames (Ditton & Greenwich)	3.3	Moldau (Prague)	16.7
Lütschine (Grindelwald)	3.7	Parana (above mouth)	19.9
Thames (Red House)	3.8	*St. Lawrence* (Vaudreuil)	23
Spree (Berlin)	3.8	Yonne (Avallon)	24.7
Danube (Vienna)	4	Garonne (Toulouse)	29
Ouroy (St. Denis)	4.2	Loire (Orleans)	30
Elbe (Hamburgh)	4.2	Máhanadi (Cuttack)	32.5
Maas (Arendonck)	4.3	*Ottawa* (St. Anne's Rapids)	33.7
Weichsel (Culm)	4.5		

Along the St. Lawrence "the granite of the main and islands is almost everywhere covered with peat, full of stagnant ponds of dark bog-water;" while the Ottawa "drains a region occupied chiefly by crystalline rocks, covered by extensive forests and marshes."[66] With the river Dee "the bounding ridges of the valley are mostly granite and gneiss," and only a small proportion of clay and peat occurs in the valley; the river Don rises in mossy ground and passes finally through alluvial meadows, assuming a brown color from peat.[67] The swampy sources or marshy banks of the Nile, Passaic, and other rivers, are well known, as well as the peaty rock-basins of the glaciated surfaces which drain into such pure waters as those of the Croton, Delaware, etc. The river Máhanadi drains "a sparsely cultivated forest country."[68] Along the Croton river, "swamps occur in some portions of the watershed, where the waters linger on peaty deposits" (C. F. Chandler). In other river-waters, however, only a trace of organic matter has been found in solution, but the percentage of silica in the residue is large: *e. g.*, the Schuylkill (9 to 15 per cent.),[69] the glacier-rivers, Möll (29.8) and Oetz (32.5), the Uruguay (46.4),[70] etc.; in such cases the solution has been effected by the water itself or by alkaline salts.

Without further considering the varied influence of local conditions, etc., it is sufficient to notice the usually low percentage of silica dissolved near the issue of the head-waters from a glacier, or from a rocky watershed, especially where the latter is underlaid by

[66] Hunt, Essays, 126; Bayfield, Trans. Geol. Soc., 1840, (2), V, 99.
[67] Dr. J. Smith, Jour. Ch. Soc., 1852, IV, 125.
[68] E. Nicholson, Jour. Ch. Soc., 1873, (New Ser.), XI, 229.
[69] M. H. Boyé, Am. J. Sci., 1850, (2), IX, 123.
[70] J. J. Y. Kyle, Ch. News, XXXVIII, 28.

strata deficient in silica; its increase with the flow of the river, especially through cultivated lands; and its excess, where the banks are rich in siliceous sands and in humus, either from peat-bogs or from high cultivation, and where the current is slow.

But this solvency of silica is, so far as due to organic matter, evidently dependent upon combination with organic acids like the azo-humic of Thenard, and proportionate to their amount. The original analyses also show that the amount of "organic matter" in solution may often be large, without a corresponding increase in that of the dissolved silica, probably and chiefly because little of the former has been in the exact condition to accomplish the solution; but a large amount of dissolved silica is almost always accompanied with a large amount of "organic matter."

§ 20. *Humus acids in mineral-waters.*—The same agency is suggested by the presence of dissolved organic matter in subterranean waters, as detected by analysis on their issue as common or mineral springs. Both in the waters and in their subaërial deposits, the proportion of "organic matter" is notable, 1 or 2 per cent. in the case of the tufa of the Springs of Saratoga, N. Y.; but only in comparatively rare instances has the exact character of this constituent been determined by the analyst: *e. g.*, the small amount of apocrenic acid in the "sprudelstein" deposited by the Carlsbad Sprudel-spring (Ragsky: *vide* Roth, *op. cit.*, p. 579). Yet both its tendency to combine with silica, and its acid nature, have been quite certainly established, and should be considered in calculations of the proximate combination of the other constituents; the absence of such consideration may have had a bearing upon some past discordance in the results of mineral-water analyses.[71]

The presence of organic matter in the thermal waters of Reickumer, in the hot springs of Iceland, etc., has convinced Bischof that "organic substances must play an important rôle particularly in the formation of mineral springs;" this he illustrates by the observation that "crenate of soda and crenate of lime possess the power, not only to dissolve a certain quantity of carbonate of lime, but also to protect a perhaps greater quantity of the same from precipitation during the expulsion of carbonic acid

[71] For example, perhaps, in that of the Trefriw mineral water, Ch. News, 1875, XXXI, 27.

by heat" (Erd. Jour. f. pr. Ch., 1834, II, 70–72, 80). It has been already suggested, that, in this group of organic acids and the other soluble organic matter of less certain character, we have a carrier of carbon to subterranean depths and thermal conditions it could not have reached in the form of carbon dioxide. It may also be that, by the slow but sure subterranean oxidation of these acids, as well as by their action upon limestone-strata,[72] vast quantities of carbon dioxide must be continually evolved, expelled by the temperature of the solutions to higher and cooler horizons, not only producing an extensive chemical erosion and alteration of the rock-material, but often collected under strata impervious to gases, and finally escaping through fissures, joints and faults. In this way may have been effected, in many cases, *the saturation of mineral-waters by gaseous carbon dioxide*, as well as its concentration and pressure indicated by the spouting through the artesian borings for water and oil. Undoubtedly in other cases, the source of the gas must be found, according to the accepted theories,[73] in its evolution from the interior of the earth, or in the reaction between silica and calcium-carbonate, etc. In the case first mentioned, the source of the dissolved organic matter, which, according to my hypothesis, has generated the carbon dioxide or other organic acids, may be found in some subterranean supply: *e. g.*, in the artesian wells of Trafalgar Square, London, the remarkably large amount of organic ("extractive") matter in the deep well-water (0.00096 per cent.), it is stated, "evidently arises from the remains of organized beings which have invariably been found in the Chalk."[74] But the dissolved organic matter may have, in other instances, a superficial origin; such a connection has been already inferred in the mineral-waters of Chambly, Moscow, Forges-les-Eaux, etc., and, in this country, we may yet have to look to the abundant peat-bogs of Saratoga, N. Y., and its vicinity, not only for the contribution of an important group of solvents—the humus-acids—of the bases found in the mineral-waters of that region, but also for the supply of the material for the carbon dioxide gas whose saturation produces their effervescence.

It has been found that the unctuosity of thermal waters, con-

[72] Hermann thus accounts for the carbon dioxide in the Moscow-water (Erd. Jour. f. pr. Ch., 1842, XXV, 208).

[73] Bischof, *op. cit.*, I, 53, 217, 236. Hunt, *op. cit.*, 8, 102, 112, 148.

[74] F. A. Abel and T. H. Rowney, Jour. Ch. Soc., 1849, I, 102. See also Hunt, *op. cit.*, 152; and R. Brandes, *loc. cit.*, 105, etc.

taining sodium sulphide, is produced by substances styled glairine, hydrosin, baregine, or "zoogene, formed of microscopic algæ, related to Hygrococis and Leptothrix," which contain a considerable proportion of silica, even over sixty per cent. In the analyses of the waters of ordinary and mineral springs, artesian wells, etc., there have been very generally reported traces of albuminoid matter, dissolved humus, asphalt, petroleum, resin, animal matter or mucus, humic extract, etc., which must probably serve as the crude materials for the constant supply of the organic acids generally associated. Of the occurrence of the latter, reported in published analyses of mineral-waters, I have compiled the following list from numerous sources, mostly well-known.

Humic acid, in the mineral-waters of Wurtemberg; *e. g.*, a trace in the Soden, Winklerbrunnen (Schweinsberg); 0.12 grain in 16 oz., Steben (Vogel); 0.157 grain, Konigswarth, Trinkquelle (Berzelius); 0.065 grain aluminum-humate, Giengen, near Brenz (Salzer); mineral-water of Tatenhausen (R. Brandes, Pogg. Ann., 1830, XIX, 98).

Crenic acid, traces in the mineral-waters of Ronneburg (Döbereiner); as ferrous crenate, in the springs of France, at Audinac, Ariége (Filhol), Campagne, Aude (Filhol), Chateauneuf, Puy-de-Dome (Lefort), Condillac, Drome (O. Henry), Vittel, Vosges (Henry), Lamotte, Isère (Henry), Martigny, Vosges (Jacquemin), Rennes, Aude (Henry), Lamotte-les-Bains, Isère (Henry); 0.002 gm. to the litre, Coise, Savoy (P. Morin); 0.02 gm., Saint Pardoux, Allier (Henry); 0.013 gm., Sermaise, Marne (Henry); sodium and ferrous crenate, Bussang, Vosges (Henry); potassium-crenate, Sentein, Ariège (Henry); 0.04 gm. ferrous crenate and carbonate, in Jonas Spring, and 0.017 gm. ferrous crenate, in Thermal Spring, Bourbon-L'Archambault, Allier (Henry); 0.098 gm. ferrous crenate, and 0.002 gm. potassium-crenate, Forges-les-Eaux, Lower Seine (Girardin & Morin, and Boutigny); 0.149 grain of torfocrenic, trace of humocrenic, and 0.235 grain of torfoxycrenic acid, in combination with ammonia and ferrous oxide, in the mineral-water of Moscow, Russia (Hermann); 0.359 grain to imp. gallon, Pitville strong saline water, 0.333 grain, Royal Old Wells No. 4, 16.825 grains, Royal Old Wells, No. 1, Cheltenham (Abel & Rowney); 0.64 grain to U. S. gallon, Chalybeate Springs of Minneapolis (S. D. Hayes),[75] etc.; Birchdale Spring, N. H. (C.

[75] Geol. and N. Hist. Survey, Minn., 1876, 199.

T. Jackson); Alburg Springs, Vt. (C. T. Jackson); 0.112 grain to U. S. gallon, Highgate Springs, Vt. (A. A. Hayes); 0.039 grain calcium-crenate, and 1.801 grain "crenate silica," Cooper's Well, Miss. (J. L. Smith); 0.312 grain ferrous crenate in the thermal waters of the Warm Springs (A. A. Hayes) and 0.108 grain crenic acid in those of the Healing Spring (W. E. A. Aikin), both in Bath County, Va.; 0.222 and 0.232 grain ammonium-crenate in the two Bath Alum Springs, Va. (A. A. Hayes); 0.455 grain calcium-crenate, and 0.01 grain ferrous crenate, Berkeley Spring, Va. (A. A. Hayes); 0.066 grain ammonium-crenate, and 0.085 grain ferrous crenate, Jordan Alum Spring, Va. (W. E. A. Aikin); 0.63 grain ammonium-crenate, Stribling's Sulphur Spring, Va. (Campbell); 0.4–0.98 grain crenic acid, (0.7–1.401 grain ammonium-crenate), Rockbridge Alum Springs, Va. (A. A. Hayes); etc.

Apocrenic and *crenic* acids, traces; Porla Spring, Sweden (Berzelius); Rochefort artesian water (Roux);[76] Lamalou, Hérault (Moitessier); ferrous crenate and apocrenate, Chateau-Gonthier, Mayenne (Henry); Alleghany Spring, Va. (F. A. Genth); 0.075 grain apocrenic acid to U. S. gallon, and 0.091 grain crenic acid, Bladen Spring, Ala. (R. T. Brumby); 0.002 grain of both acids, Catoosa Spring, Ala. (W. J. Land); ferrous crenate and apocrenate, Seneca Spring, S. C. (W. J. Land); 0.137 grain crenic, 0.099 grain apocrenic, to imp. gallon, Trafalgar Square artesian water, London (Abel & Rowney); 0.243 grain crenic, 0.147 grain apocrenic, Cambray Spring, Cheltenham (Abel & Rowney); 1.025 grain crenic, 1.415 grain apocrenic, Bristol, England (Herapath)[77]; 0.0046 per cent. ferrous crenate and apocrenate, in the thermal waters of St. Allyre, near Clermont, France (Girardin)[78]; 0.00186 per cent. crenic and apocrenic acids, with traces of *propionic* and *formic* acids, in the Eckholtz Spring, Ronneby, Sweden (Hamberg).[79]

Formic acid, trace, in the water nearly saturated with carbon dioxide, Carlsbrunn, Austrian Silesia (Schneider);[80] 0.0048 gm. formic acid to the litre, with trace of *acetic acid*, St. Boes, Pyrenees (Garrigon).[81]

[76] Jour. de Ph. et Ch., 1872, Feb.
[77] Jour. Ch. Soc., 1850, II, 200.
[78] Ann. d. Mines, 1837, (3), XI, 458.
[79] J. pr. Ch., 1860, 80, 396.
[80] Proc. Acad. Vienna, 1862, Apr. 2.
[81] Am. Chem., 1873, IV, 320.

Butyric acid, trace, Old Crescent Well, Harrogate, England (Fairly).[82]

Mellitic acid (?), *Geic acid*, etc., in mineral-waters of France (P. Labarthe, Les Eaux Min., etc., de la France, 1873, 3).

The survival of traces of acids of such complex constitution may have therefore great significance; and it is important to remember that the presence of even the minute proportion, styled *a trace*, in the waters of a spring of free and constant flow, implies the annual delivery of a large absolute amount.

The use of the term "organic matter," in the thorough examination of mineral-waters, may yet become obsolete, as indicating too gross an imperfection of analysis; and the exceptional cases, in which the organic constituent of waters or solid substances has already been determined with exactness, may yet be searched for by future workers as at last possessing, for certain purposes, an invaluable significance.

The influence of the character and amount of nitrogenous organic matter in solution upon the potability of waters is well known. The suggestive observations of a few analysts hint also at the possible assignment, to the organic constituents in certain mineral-waters, of the subtle agency to which their therapeutic value is due; for example, for the supply of a ferruginous salt in the form most assimilable in digestion, or more directly, if highly nitrogenous, in scrofulous diseases, etc.[83] Instances of the occurrence of such acids in mineral-waters have just been given, and a single illustration of their indirect action will suffice. The Greenbrier White Sulphur Springs of Virginia contain in a gallon, by the analysis of Mr. S. D. Hayes of Roxbury, Mass., 11.29 cubic inches of carbon dioxide. The saline matter in 50,000 grains consists chiefly of calcium and magnesium-sulphates and calcium-carbonate, and also contains,

Organic matter, 3.74; Silica, 1.34, etc.

"The alkaline bases are also in very small proportion, and seem to be united to the siliceous earths in combination with a peculiar organic matter. The organic matter in its physical and chemical character resembles that found in the water of the Red Sulphur Springs, and differs essentially from the organic matter of some

[82] Ch. News, 1874, XXX, 151.

[83] Boutigny, Compt. rend., 1871, LXXIII, 249; Brandes, *loc. cit.*, 93.

thermal waters. * * * * The medicinal properties of this water are probably due to the action of this organic substance," through the generation of sulph-hydric acid from the earthy sulphates.

ACTION WITHIN LOOSE DEPOSITS.

VI. Sands and Gravels.

§ 21. *General chemical action.*—The published observations on the chemical action of the acids of humus in nature are rather of limited character, and have hitherto been naturally confined to agricultural chemistry and to the formation of bog-ores. The great work of Bischof, to which reference would naturally be made for information on this subject, is found to be extremely deficient, in view of *recent* investigations; and it seems therefore desirable first to consider briefly those views of this author which pertain to this field. His chief, almost only, discussion of the group of humus-acids is contained in a few pages of the first volume of his work. He describes the general properties and reactions of humic, crenic and apocrenic acids, and states that "in marshes and morasses there is then no want of acids which are capable of dissolving protoxide and peroxide of iron, and Kindler's observations show that such solutions really take place."[84] The only acid or constituent of humus, however, with which he afterwards connects general and actual *solvent* action in nature is carbon dioxide, and this is fully and constantly referred to throughout the work. The influence of "organic matter" is, it is true, frequently considered, but almost always as merely the *reducing agent* of sulphates and higher oxides, preparing the bases for solution in the great menstruum, carbon dioxide (*op. cit.*, I, 52, etc.). In regard to the solution of iron-oxides, he evidently believes that ferruginous waters must be necessarily almost always carbonated, and even states that "hydrated peroxide of iron is never present in water" (II, 467), disregarding the ammoniacal solutions of the crenates, etc., to which he had already made reference (I, 166). In fact, the existence and influence of the double salts of the humus-acids, which now appear to us to be the main agents for initial solution and decomposition, are ignored by Bischof. In regard to silica, he recognizes and frequently refers to "the remarkable affinity of organic matter for silica" (I, 187, 189), and to the view that "organic

[84] Chem. and Phys. Geol., I, 166.

matter in any combination precipitates silica from its solution" (I, 312), etc.; but for its transport in nature, he constantly resorts to its solvency in natural waters, usually at the ordinary temperatures, which he considers chiefly dependent upon the amount of sodium-carbonate present and never exceeding $\frac{1}{1000}$ (II, 454). The ferrous silicates, which occur in the residues deposited by waters or resulting from their action, and whose existence as such he founds on the presence of silica in iron-ochre, he continually regards as in solution in natural waters and exerting chemical action (I, 4): without reference to the organic media—ferrous silico-azo-humates—which, in all probability, accomplish both the solution of silica and iron and the chemical action of their solutions. He often frankly admits himself at a loss to account for certain phenomena by their action (III, 543, etc.); and notwithstanding therefore the attractiveness of his views on these subjects, on account of the simplicity of the agencies he invokes, later investigations have proved that in nature the agencies, as well as their effects, are highly varied and by far more complex.

From the rather antiquated portion of chemical literature which forms the basis of present views, only those facts will be now selected which bear chiefly upon the conditions *antecedent* to the formation of deposits of hydrated ferric oxides.

A. Kindler[85] observed that decaying roots, traversing ferruginous quartz-sand, absorb the rain-water filtering through, and, by decomposition, yield acids which dissolve the oxides of iron out of the surrounding sand, sometimes to a distance of one or two inches. So that in summer a cylinder of decolorized sand surrounds the root, or even a considerable layer may be so bleached when the root is large and much decayed. "This phenomenon also presents itself in woods and gardens; decolorized sand is found everywhere under rotting leaves . . . If a decaying root and quartz sand, colored with oxide of iron, are often moistened with water, it will be found ferruginous, after filtering and evaporating. This process of decay acts, therefore, as a powerful deoxidizing agent." He supposes that an organic acid has been formed which reduces the iron and dissolves it in the form of a protoxide salt; the latter is carried off by rain-water, is oxidized by the air to an insoluble basic combination, and then deposited

[85] Pogg. Ann., 1836, XXXVII, 203.

on the bottoms of bogs and morasses into which the water flows. To this observation Berzelius[86] added that he found a bog-earth to contain basic crenate and apocrenate of iron-oxide, that these acids are formed during the decay of plants, and their ferrous salts are soluble in water. In this fact he found one of the means by which iron-ochre is concentrated in lakes and bogs by transference from ores disseminated through soils and rocks.

From the careful observations of Daubrée[87] upon the continuous formation of bog ores in marshes, etc., in the plain of the Rhine and Lorraine, the following quotation may be translated, relating to the initial conditions of the deposit:

"1. The peroxide of iron, intermingled with deposits of little coherence which contain vegetable matters in decomposition, is dissolved by the infiltrating meteoric waters, under the influence of certain products of the decay of these plants.

"2. It is by the action of carbonic acid and crenic acid, that the peroxide of iron, reduced, at least partially, to the state of protoxide by the presence of the contiguous vegetable matter, appears to be brought into a state of solubility in water . . . .

"3. Everywhere where the water of these springs flows slowly in contact with air, it leaves behind, particularly during the summer, a gelatinous mud of a blackish brown color, which is principally composed of protoxide and peroxide of iron, combined with carbonic acid, crenic acid and water. The oxide of manganese is rarely wanting, and its presence is probably due to the same reactions as those of the oxide of iron. The carbonic acid is disengaged in proportion as the protoxide of iron passes into the state of peroxide, and ultimately, after the substance has been dried at the ordinary temperature, naturally or artificially, only traces of this acid remain.

"4. If the precipitate of the spring has been confined several days in its basin, it is in addition intermingled with many siliceous shells of infusoria belonging to the genera Navicula and Gaillonella, as well as very numerous filaments of Oscillaria.

"5. The deposit formed around each spring is transported during high waters into a brook or river of the vicinity; the same thing occurs with that part of the ferruginous combination, which, not having yet been decomposed, has remained in solution. As

[86] Berzelius Jahresb., 1838, 17, 211.
[87] Compt. rend., 1845, XX, 1775.

long as this brook or this river flows rapidly, it deposits nothing upon its bed; but everywhere, where the rapidity of these watercourses is considerably retarded, particularly in the pools of stagnant water which they supply not far from their beds, the oxide held in suspension, and that which is yet in solution, are little by little precipitated; then the deposit, infiltrating laterally into the sands, proceeds to contribute to the increase of concretions in the form of veins and nodules, which, at the end of a certain lapse of time, become exploitable as iron-ore."

The author further considers the deposits of ore thus produced in bogs and their relation to the associated peat formed under the same conditions, viz., of shallow water renewed constantly but at a very slow rate.

J. F. Johnston also states, in regard to another common result of the vertical percolation of natural ferruginous solutions:

"In sundry districts the decaying vegetable matters of the surface soil are observed to sink down and form an ochreous *pan*, or thin yellow layer, in the subsoil, which is impervious to water, and through which therefore the rains cannot pass. Being arrested by this pan, the rain-water, while it rests upon it, dissolves a certain portion of the vegetable matter, and when collected into wells, is often dark-coloured, marshy in taste and smell, and unwholesome to drink."[88]

The same product has been also thus described: Hardpan is a dense, almost impenetrable, crust or stratum of ochrey clay or compacted gravel, often underlying a fairly fruitful soil. It is the soil reverting to rock, the particles being cemented together again by the solutions of lime, iron, or alkali-silicates and humates that descend from the surface soil. Peat swamps thus exist in basins formed on the most porous soils by a thin layer of *moor-bed-pan*.[89]

Detmer and others have given similar descriptions. Johnson also observes,[90] on the agricultural relationships of the chemical reagents which have produced these natural solutions: "the organic acids of the humus group probably aid in the disintegration of soil by direct action; . . The ulmic and humic acids themselves, according to Mulder, indeed do not exist in the free state

[88] The Chemistry of Common Life, 1876, 36.
[89] S. W. Johnson, How Crops Feed, 1870, 156.
[90] *Idem*, 139.

in the soil, but their soluble salts of ammonia, potash, or soda, have acid characters, in so far that they unite energetically with other bases, as lime, oxide of iron, etc. . . The same is probably true of crenic and apocrenic acids."

§ 22. *Induration of calcareous sands.*—The high content of carbon dioxide in seawater, which has been found[91] to be dependent upon the magnesium and calcium sulphates in solution, has produced within the tropics, in spite of the elevated temperature, a partial solution and cementation of the coral sands, resulting even in the consolidation of beaches. These commonly occur in many islands of the Atlantic,[92] *e. g.*, Madeira, St. Jago of the Cape de Verdes, Ascension, St. Helena, etc.: of the Pacific, *e. g.*, in the Paumotus, Navigator and Hawaiian groups:[93] of the West Indies, *e. g.*, Guadaloupe, Sombrero, etc.: along the coast of Brazil:[94] and of vast extent on the Australian shores. Even in some of these cases, however, Hartt indicates his suspicion that the solidification has been affected by the percolation through the beach of the "black waters" from the inner lagoon;[95] and this seems the more likely from the recent discovery of a second indurated layer at a depth of about 18 feet,[96] unless this may have been produced simply by subsidence of the coast. The drift sand-rock or "Æolian formation" of consolidated calcareous sand-rock, which constitutes the Bermudas and the islands of Oahu and Kanai in the Pacific,[97] has had certainly no connection with the carbon dioxide of seawater, but only, according to R. J. Nelson[98] and Wyville Thomson,[99] with that of falling rains. The warm rains can carry but a small content of that gas out of the atmosphere, and yet the work continually in progress in the Bermudas, in the consolidation of the blown sands, in the excavation of caverns, in the formation of the huge stalactites and concretions, etc., indicates an enormous and constant supply of solvent. That this is largely generated within the layer of soil (which contains

[91] J. Y. Buchanan, Proc. Roy. Soc., 1874, 483; also, Depths of the Sea, 115, 343, 518–9.
[92] C. Darwin, Geol. Obs., 1876, 56, 98, 161.
[93] J. D. Dana, U. S. Expl. Exp., Geol., 1846–1849, 44, 148, 153.
[94] C. F. Hartt, Geol. and Phys. of Brazil, 1870, 107, 113, 179, 342–345.
[95] Hartt, *op. cit.*, 115, 343.
[96] J. C. Hawkshaw, Geol. Mag., 1879, New Ser., VI, 91.
[97] Dana, *op. cit.*, 45, 64, 254, 277.
[98] Trans. Geol. Soc., 1840, (2), V, 103.
[99] Voy. of Chall., Atlantic, 1878, I, 292.

about 15 per cent. of organic matter), though partly from the organic component of shells and corals, seems to be more definitely shown by the strata abounding in tubular deposits around rootlets (Nelson, *loc. cit.*, 110–111), by the particles of black carbonaceous matter as well as the organic membranous tissue still remaining in the shelly sand, and by the relationship of the soil to the deposits of "red earth," covering the surface to the depth of about a foot (Nelson, *loc. cit.*), especially, according to Thomson, *in the hollows*. In this the proportions of vegetable matter are less but variable: the soil, according to the analyses of Buchanan, containing about 20 per cent. of siliceous sand and 51 per cent. of ferric oxide and alumina; while, in the red earth, the amount of sand rises to about 31 to 40 per cent., and that of the bases just mentioned has been leached out down to 26 and even 17 per cent. The process appears to be analogous to that which has yielded a part of the "red clay" of the deep sea ooze, the organic acids of the soil having dissolved the calcium-carbonate out of the superficial layer of coral-sand, and concentrated, to the degrees above stated, its content of silica (0.05 per cent.) and of the same earthy bases (0.52 per cent.). The occurrence of "a small quantity of manganese" in the red earth is a suggestive fact, noted by Nelson, in his list of the few minerals found in these islands (*loc. cit.*, p. 105). At Raine Island,[100] one of the New Hebrides in the Pacific Ocean, a reddish tint affects the calcareous sand and its consolidated crusts, "immediately above the beach-line, where the grass commences," and probably indicates the incipient attack of the same solvent agency. Calcareous sands are also sometimes found consolidated into crusts around decaying stems of plants,[101] and left projecting as hollow tubes by the decay of the wood and removal of the loose sands.

§ 23. *Induration of siliceous sands.*—The loose Tertiary sands of the north of France exhibit a remarkable cementation, locally, by calcium-carbonate and by silica;[102] and a similar cementation of sands and gravels by ferric oxide has been observed at many localities in the valleys of the Rhine and Ahr.[103] All these proc-

[100] H. N. Moseley, Notes by a Nat., 1879, 347.

[101] At Cape of Good Hope, Moseley, *op. cit.*, 149; in Australia, C. Darwin, Jour. of Res., 1871, 540.

[102] Jukes, Man. of Geol., 121.

[103] Bischof, *op. cit.*, German ed., 1863, I, 565.

esses have probably been effected by the percolation of solutions of lime, iron-oxides, etc., in the salts of the humus-acids, etc. The bleaching of ferruginous sands by the same action, when they are rich in plant remains, has also been studied in the Brown coal and Cretaceous formations of Germany.[104] I have recently given elsewhere a description[105] of indurated layers of sand and gravel in the Tertiary and Cretaceous areas of New Jersey, with a resumé of the similar recorded observations. Their cause was assigned, in the New Jersey sands, to certain of the more soluble humus-acids, not yet exactly determined, whose continuous formation appears to be favored especially by the nature of the exuviæ of the pine, the warm moist climate of the region, and the porous aerated strata below. The oxide of iron, leached out of thick layers of the yellow sand, is deposited and concentrated within the interstices of alternating layers of the coarser sands and gravels, indurating them into a compact and generally conglomeritic sand-rock. This latter process is found to have been increased, if not occasioned, by the presence of the abundant pebbles of a yellowish chert, which have been partially and indeed largely replaced by iron-ochre, while the crystalline and even chalcedonic varieties of quartz have been unaffected. The former have been evidently derived from the chert layers of a Devonian limestone; and if their amorphous material was originally segregated there, as I shall explain beyond, by the action of organic acids akin to those of humus, it is easy to see that their present molecular condition, as well as porosity, has rendered them easily re-soluble in a similar solvent.

Now carbon dioxide, and indeed many other of the humus-acids, could have had little to do with this solution; the humic and azohumic acids can alone solve the problem, and it is probable that these have predominated in quantity among the group of organic solvents which have percolated through the sands and reduced and leached out the ferric oxide in ferrous combinations. The heavy deposition of hydrated ferric oxide chiefly in the coarser layers, especially the gravels, seems to imply an oxidation occasioned in part by the large air-spaces among the pebbles. But the substitution of the same substance in place of the chert indicates

[104] *Idem.*, 566–7.

[105] "On the Induration of Sands by Ferric Oxide, and its Precipitation by Chert."

apparently the peculiar efficiency of these acids, for the solution of silica, in their *nascent condition*, on the partial separation of their oxidized base. The large amount of the ferric hydrate, which was consumed in the cementation and complete induration of these gravels, appears therefore to have been yielded through its abundant separation in the presence of the chert; in the absence of that substance, it is probable that the ferric oxide would ultimately have been mostly conveyed, unhindered by the gravel, to lower levels of drainage or into the basins of sub-aërial deposit as bog-ores. These phenomena therefore seem to indicate that the strongest solvents of amorphous or colloid silica in nature consist of a group of certain organic acids of humus, when separated from ferrous oxide by its higher oxidation: perhaps, also, that the silico-azo-humic acids thus formed enter into little or no combination with ferric oxide. Probably during further conveyance through the sands, these silicated organic acids are accompanied in solution with sufficient organic matters to reduce and bring into combination a new burden of iron-oxide. It is not always safe to attempt by field observation to anticipate the chemical reactions of little known substances; and we must look forward for exact and certain information on this subject to the full publication of the long-promised results of Thenard's investigation.

It may be further remarked, in reference to the continuous supply of air for the oxidation just described, in subterranean cavities, that the percolation of waters through such bodies of sand is always intermittent, being chiefly dependent upon the repeated showers of rain upon the surface. The effect of each mass of water, percolating after a shower, must be ultimately to draw down *with it* the gaseous atmosphere of the sands, rich in nitrogen, and *after it*, by atmospheric pressure and capillary attraction, new supplies of pure air from above. Though the mass remains almost constantly damp, through the occupation of the finest interstices by capillary moisture, there are natural vertical channels for the main percolation, apparently shown in the fibrous variety of sand-rock with vertical tubes, through which the drainage is mainly conveyed in the endless repetition of the foregoing process. The destination of the solutions, now rich in silica, will be the subject of further investigation.

§ 24. *Purification of Beach Sand.*—The purity of the sand and the whiteness of the dunes, along the New Jersey coast,[106] have been the subject of frequent remark by the passing traveller and artist. The same characteristics probably prevail along the whole ocean front, from the dunes of Cape Cod to those of the Carolinas. But this whole tract consists of a definite series of belts, passing from inland to the beach, viz.:

First, a loose mass of ferruginous sands, with some clays:

Secondly, a broad fringe of fresh-water swamps and peat-bogs, passing gradually into salt-marshes, rich in acid solvents, upon the surface; and underneath, at a slight depth, frequently an indurated layer of cemented sand-rock or hard-pan:

Thirdly, a long sea-channel or inner bay, swept by the tidal currents, by which all drainage solutions and suspended impurities from the land are constantly scoured out into the sea:

Fourthly, an interrupted narrow fringe of marshes, lining the inner side of the beach: and

Lastly, the long, narrow beach of pure siliceous sand, washed up by the waves and blown about by the winds. On examination of this sand at several points of the New Jersey coast, from Egg Harbor Inlet to Sandy Hook, I have found it to consist almost entirely of rounded and sub-angular granules of limpid, white, and reddish quartz, basanite, and polished black iron-sand, possessing no magnetic attraction.

The inner bay, with its fringing deposits of decomposing humus, therefore forms a great acid basin or vat for the digestion and purification of the ochreous sand. This purification has, I believe, been hitherto attributed to mechanical attrition under the action of the surf, and has been disguised by the black and fetid muck of the salt-marshes which envelopes the siliceous grains. But beneath or intermingled with the superficial mould under every pine and cedar forest on the land, and underneath the current of flowing water in every ditch through the marshes, gleams out exactly the same intermixture of white quartz-sand, with a little black iron-sand, as the winds and the waves toss back and forth upon the outer beach; and, in the latter, Cook reports, in addition to grains of quartz and iron-sand, only about one per cent. of

[106] Also on the coast of Brazil, according to Hartt, *op. cit.*, 380.

and look down upon the black, marshy surface, usually concealed beneath the sea and sand. This sometimes still retains the hoof-prints of cattle which formerly grazed upon the marsh when above the sea-level, now in long lines which descend toward the depths of the open ocean and which present an impressive illustration of the progressive subsidence of the coast. All along this beach (as far to the northward as Long Branch, according to Prof. D. S. Martin), the force of the waves, during storms, has been sufficient to tear up fragments of the submarine peat-bed, which are found scattered above the surf-line and are often penetrated by boring-shells. Where the outer beach has advanced, by the heaping up of the sand by surf and wind, the salt marsh, more or less intersected by creeks and the inner bays, may extend from one to six miles in width, projecting inwards along the streams to far greater distances and so passing gradually into the swamps of the uplands. At other points, the tidal currents have swept away to seaward all this band of loose, purified deposits, and the surf beats directly upon the mass of ferruginous sands. And thus by intermittent advance and recession, these chemical and mechanical agencies alternate in their work for the common end—the purification of the littoral deposits of sands and clays.

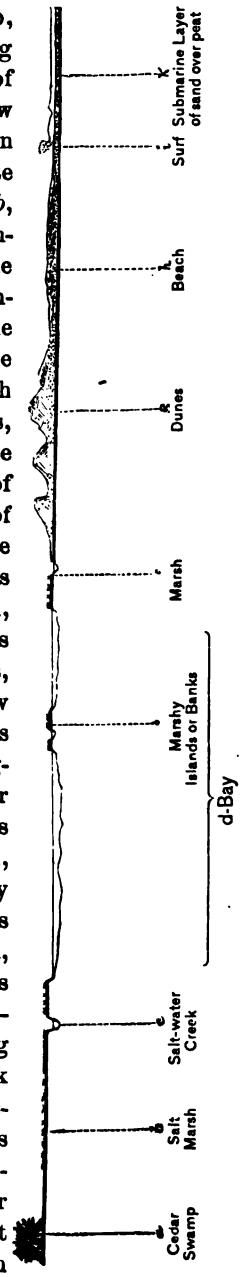
VII. Action Upon Clays.

§ 25. *Champlain Clays.*—The distinction of the Champlain clays into "blackish-blue, bluish-grey" and "yellowish-grey, greyish-white" seems to have been first made in the Hudson Valley, in a paper by John Finch,[108] and afterwards by Eaton.

In the geological survey of the State, Mather gives full and precise descriptions[109] of the two layers of clay, under the names "grey or buff-colored" and "blue," and points out the invariable superposition of the former in New York, with the "line of junction generally very distinctly marked," but a more irregular arrangement of the same clays in Ohio, Illinois and Michigan. He also describes (*l. c.*, p. 251) similar differences in color between the upper and lower layers of the Tertiary clays of Long Island. Along the bank of the Hudson, these deposits are very thick, often over 180 feet; and at Newburgh, I observed the upper layer of the clay beds, to a quarter of their depth, to be much mixed

[108] Am. J. Sci., 1826, X, 227, 229.
[109] Nat. Hist., N. Y., Geol., 1843, Pt. IV, I, 125, *et seq.*

ocean. At *a* is the edge of the cedar-swamp, and it is interesting to notice that on thrusting anywhere through the springy moss bottom of the swamp into the clear brown water, a few inches underneath, the latter is found to be in steady motion, flowing at an appreciable rate toward the bay. Next comes the salt-marsh, *b*, overflowed by the higher tides over an area indicated by the predominating salt-grass. The fresh-water streams from the uplands pass into the natural creeks, *c*, which intersect the marsh. Their bottoms are covered by the black marsh mud, sometimes mingled with shells from ancient mounds or shell-heaps, which have been carried down, in the course of the gradual subsidence, within the reach of the tides. Wherever, however, the force of the current is sufficient, the bottoms of these creeks and especially of the artificial ditches in the salt-marsh are covered with white sand, intermingled abundantly with the siliceous valves of diatoms. The section next presents, though on a too contracted scale, the shallow waters of the bay, *d*, interspersed with islands or submerged banks, *e*, which represent fragments of the original salt-marsh. The outer beach is also underlaid by this, sometimes projecting as a fringe, *f*, uncovered by sand, on the inner side; its centre is occupied by the dunes, *g*, with the usual irregular cross stratification; and beyond comes the beach, *h*, in which the thinly laminated sand-layers incline gently (at about 9°) towards the sea—the structure in both dunes and beach being accentuated by the sorting out of the black grains of iron-oxide by wind or water respectively. Beneath the surf the beach-sand is continued in a thin layer, which, after a violent storm, is sometimes stripped off, together with portions of the beach itself: so that, at such a time, one may stand upon the beach



are stained with films of iron-ochre. Below, it is sometimes separated by a thin layer of sand, from the blue clay, and sometimes "changes gradually near the bottom into blue clay" (*l. c.*, pp. 154, 155). At Rochester occurs what he terms an "anomalous section" (*l. c.*, p. 155), and which is in fact the most satisfactory in determining that the relation of the two clays is simply one of decomposition. Here the blue clay projects horizontally in a great tongue-like mass into a layer of the gray clay, fifteen feet thick, the lines of stratification being continuous through both.

The same differences, in oxidation of iron and in color, exist in the layers of glacial till, which Hitchcock has distinguished by the terms "Upper" and "Lower;" and he suggests that the differences may have been produced by derivation of the blue clay from the lower till, and the gray from the upper till or from the washing of the upper terrace deposits. G. W. Hawes, however, attributes the increase of iron in the clays over the tills, as shown by his analyses (*loc. cit.*, p. 333), to the ready transport of the fine ferruginous material along with the bulk of the clay, and explains the difference in oxidation of the iron in both the tills and clays thus: "if the beds of both till and clay, as first deposited, were of the same nature as the lower beds at present, atmospheric and aqueous agencies would in time produce the differences in both now seen." Nevertheless the division of the till into two classes, by Hitchcock, is probably well grounded, as well as his explanation of their differences; though there is need of a clear distinction between the true upper till and the bleached upper layer of the lower till, wherever the latter is superficially exposed, *e. g.*, at the Geyser Spring of Saratoga, N. Y. On the other hand, in regard to the two clays, all the observations appear to establish the correctness of Hawes' explanation; though I think we can refer to the definite sources of the chemical action.

In regard to both the lower till and the clay the following inferences may be drawn. The entire stratum of each, when first deposited, was substantially of the same nature and composition —that of the layer now found below. The heavy vegetation, which originally clothed the surface, the rich soil superposed, and the percolating meteoric waters, have given rise to solutions of the humus-acids, which have permeated the superficial layers, decomposed the finely divided silicates, and dissolved all readily soluble salts, especially of lime and ferrous oxide, and carried them off.

Although capable of overcoming the density and impermeability of the clay, the action of the solvent seems to have been facilitated to a considerable degree by the numerous intercalations of layers of porous sand; and the present depth of the upper brown layer is the measure of the extent of this alteration and lixiviation, since the original deposit of the stratum.

Jos. LeConte has also shown that the difference between the blue and the overlying red argillaceous gravel, occupying the old river-beds of California, has been due entirely to a similar process of the downward progressive oxidation of the iron.[112]

§ 26. *Cretaceous clays, etc.*—In New Jersey many passing observations[113] on the clays, possibly Cretaceous, indicate the results of a similar process of alteration, often associated however with the results of decomposition of *pyrite* and apparently of the glauconite also. In these beds the white or light-colored sands and pipe-clays (sometimes blackened by carbonaceous matters) generally overlie others of darker shades of blue and brown, or are sometimes intermingled with them, when intercalations of porous sand-beds occur. Sometimes the blue clay is mottled or spotted with irregularly mixed red and white masses, or stained near the surface by oxide of iron in filmy coatings on cracked surfaces. The lower part of the buff clay, as well as the pipe and fire clays, often contain 37 to 39 per cent. of alumina, and less than 1 per cent. of ferric oxide; while in the brick clays the percentage of alumina is 17 to 21, and of ferric oxide, 4 to 6. Beneath the clay-beds stony ferruginous crusts and layers are sometimes observed, consisting of cemented sand or of cemented sand and clay. A process of alteration has also been reported[114] in the greensand deposits of New Jersey, as shown by the induration of barrel-shaped masses of green marl. While this is doubtless true, there are certainly other cases I have observed, as in the indurated greensand of the Navesink Highlands, in which the glauconite grains are found, on microscopic examination of thin sections, to be cemented by a very minute granular mass of the original calcareous organisms; in some specimens the foraminiferal forms are visible to the naked eye. It seems likely, therefore, that one effect of the solutions of humus-acids, continually percolating

[112] Am. J. Sci., 1880, (3), XIX, 180.
[113] G. H. Cook, Report on Clays, 1878, 66, 85, 102-5, 195-239, 258.
[114] Rogers, Geol. of N. J., 1840, 197.

through this deposit, is to *dissolve out* its calcareous cement, as in the deep-sea ooze, afterwards described. The present loose uncompacted character of the greensand deposits may therefore, perhaps, be merely the result of such recent chemical solution and disintegration.

It has also been shown that the white Cretaceous clays, and the white fire-clays[115] and pipe-clays of the Coal-measures,[116] rich in alumina, and almost exhausted of iron and of the more soluble bases, as well as the gray sandstones and shales which always accompany the coal, demonstrate the leaching effect of the organic acids; the decoloration of the surface in red-clay soils, and the marbling of clay and bleaching along crevices, have been also assigned to the same cause. The white fire-clays of Pennsylvania enclose the marks of innumerable roots of stigmaria, etc., showing that they must have been crowded with vegetable remains.[117] I have also noticed that the clays in caves, as at Howe's Cave in Schoharie County, N. Y., are apt to show by their color, tenacity, etc., that they have experienced the same removal of iron oxide and concentration of alumina, by chemical action—probably of organic acids in the rain-waters which flood the cavities during and after storms.

VIII. Alteration of Fossils.

§ 27. *Silicification of fossils.*—It may well be suspected that the silicification of calcareous fossils, presented on so large a scale in the Eocene buhrstones, may in some cases have been caused by organic acids, possibly derived from the decomposition of the associated lignites; and that such silicified strata may have been thus produced by an induration of antecedent sands or marls, as well as by the alteration of beds of solid limestones. It has been observed that lime and silicic acid frequently occur together as agents of petrifaction; siliceous crusts occur even in recent calcareous corals, and quartz-crystals are often found in the chambers of ammonites.[118] The silicification of wood, so abundant in Cretaceous and Tertiary deposits, may not always need for explanation the application of thermal solutions of silica, but rather that of this familiar but widely-distributed chemical agency, whose effect may in some cases have been even assisted and accelerated

[115] Hunt, *op. cit.*, 13, 227.
[116] LeConte, El. of Geol., 136, 374.
[117] Rogers, Geol. of Pa., II, 737.
[118] Roth, *op. cit.*, I, 611.

by the high temperature of the waters. This subject is further considered beyond (§ 59).

§ 28. *Obliteration of fossils.*—Another result consists in the solution and obliteration of fossils, especially those of a calcareous nature, enclosed in porous masses of gravel, sand and clay, even when indurated. The absence of sea-shells from one such stratum, in Brazil, is stated to be "largely owing to the fact that they have been dissolved out by rains."[119]

Their general absence from extensive modern deposits, in South America, has been explained by the certainty of their disappearance from the surface by alluvial action and dissolution in rain-water.[120] In the Champlain deposits of this country, the scarcity of fossils is generally remarkable; they seem to be almost altogether confined to the blue clay,[121] which has been shown to be the remnant of the deposit but little affected by the acid waters infiltrating from above. It is even a question how far the marly character of most of these clays may be due to later and perhaps recent alteration, by such solvents, of former abundant enclosures of shells.

Again, the great Loess-deposit in this country, as also in Europe and China, is characterized by a significant absence of almost all fossils but those of a few terrestrial mollusks, *except where the material is clayey.* Richthofen, Pumpelly and Todd, have called attention to the abundance of fine tubular cavities, branching downward like root-marks, mostly confined to the upper portion of the Loess, being rare at a depth exceeding thirty or forty feet. The views of these observers, advanced on the still mooted problem of the origin of the Loess, have been partially founded on this absence of marine organisms; but Hilgard, in a recent paper,[122] suspects the connection of this absence from the mass of the deposit with the solution and re-deposition of calcium-carbonate, which at least he shows to be constantly and rapidly going on. Whether marine or terrestrial, vast numbers of shells appear to have been dissolved up, and their material often concentrated in the calcareous concretions which abound through the Loess. He made similar observations,[123] both on the scarcity of fossils and the associated abundance of calcareous concretions,

[119] C. F. Hart, *op. cit.*, 82.
[120] C. Darwin, Geol. Obs., 1876, 415.
[121] Geol. of N. H., III, 165-166.
[122] Am. J. Sci., 1879, (3), XVIII, 108.
[123] Smith's Cont., No. 248, (1872).

of a red residue of similar composition to the "red clay," on treating a sample of globigerina-ooze with a dilute mineral acid. J. Murray states, "the most potent agent concerned in the removal of these shells from the majority of the deep-sea deposits is very likely that suggested by Prof. Wyville Thomson, viz., carbonic acid; yet there may be others." According to his view, however,[131] the genesis of the red clay has been due to the decomposition of feldspathic minerals, detected by the microscope in the ooze, which have been poured into the ocean in suspension by rivers and by atmospheric showers, viz., pumice, feldspar and sanidine, as well as augite, hornblende, quartz, leucite, magnetite, mica and olivine.

However, no experimental proof has yet been presented of the ability of carbon dioxide to overcome, in so short a time, the resistance to decomposition of the chitinous tissue of a recently living shell, and the protection from solution it affords to the enveloped calcium-carbonate. The known feeble influence of carbon dioxide upon the pumice, etc., especially under the conditions of temperature, etc., at the sea-bottom, renders it further probable that the chemical action has taken place *chiefly upon the bottom, within the ooze*, and at an inconceivably slow rate.

Again, nodules[132] have been found abundantly in the red clay, which consist mainly of manganic oxide, in part of ferric oxide. They are "round, oval, or mammillated, and very irregular, varying in size from a grain of mustard seed to a large potato." They possess a concentric structure, with a radiating fibrous arrangement, and "appear to form loose among the soft clay." The corals, otoliths, teeth, siliceous sponges, etc., which are often largely disseminated through this variety of ooze, frequently display a metasomatic alteration into the same concretionary material; and fragments of pumice or other minerals often constitute the nuclei.

Indications of flint,[133] of a somewhat indefinite nature, have been also frequently noticed, apparently occurring only where siliceous organisms were absent. Sometimes it was represented by a siliceous cement, binding together the shells of the ooze, in a gray flinty-like matrix; sometimes by small angular and soft pieces

[131] Proc. Roy. Soc., 1876, XXIV, 531; Voy. of Chall. Atl., II, 253-255.

[132] Thomson and Murray, Proc. Roy. Soc., 1876, XXIV, 39, 464, etc.; Voy. of Chall., Atl., I, 169, 189, etc. Also in Loch Fyne, J. Y. Buchanan, Nature, 1878, XVIII, 628.

[133] Murray, *idem*, 491, 517, 524, etc.

of a cherty-like mineral; and sometimes by a yellow and green siliceous nucleus to the manganese nodules, occasionally presenting agate-bands.

In the bottom of the Pacific, the clay is sometimes found "in a peculiar concretionary state, run together into coherent lumps," or the blue mud has even experienced an induration into large pieces of rock, raised by the dredge, which are "merely hardened portions of the bottom."[134]

§ 31. *Organic matter in the ooze.*—Considerable evidence now exists that a substance corresponding to humus, simply in its yield of acid solvents of lime, oxides of iron, manganese, etc., enters universally into the constitution of the layer of ooze upon the bottom of the ocean. Its exact composition has never yet been determined; but it may be suspected that it resembles that of *glairine* (§ 20), especially in its high content of silica. As it has resulted from the continuous decomposition of the cellulose membranes of the diatomaceæ, etc., and of the gelatinous sarcode of the radiolaria, spongiæ, and foraminifera, which may be there living or deposited by subsidence from the surface, its composition must differ widely from that of the humus of subaërial eremacausis, in its large proportion of water and nitrogen and in its poverty in carbon. It must thus present the most favorable conditions for rapid dissociation.

Concerning the globigerina-ooze, it is said, "the stomachs of the more highly organized animals living in it or on its surface are always full of the fresher foraminiferal shells, from which they undoubtedly derive not only material for the calcification of their tests, but nitrogenous matter for assimilation likewise."[135] Indeed Ehrenberg found long ago that the foraminiferal shells at the bottom of the ocean are "not empty, but are often filled with organic substance;"[136] and a transparent gelatinous matter has been since observed by Huxley, and called *Bathybius*, in the form of innumerable minute lumps, scattered through the ooze, "forming a living scum or film on the sea-bed . . . . so that it probably forms one continuous scum of living matter girding the whole surface of the sea-bed:" and by Mahony, as particles still occupy-

[134] Thomson and Murray, *idem*, 33, 499, 504, 506, 529, etc.
[135] Thomson, Voy. of Chall., Atl., II, 283.
[136] Bischof, *op. cit.*, III, 109.

of a red residue of similar composition to the "red clay," on treating a sample of globigerina-ooze with a dilute mineral acid. J. Murray states, "the most potent agent concerned in the removal of these shells from the majority of the deep-sea deposits is very likely that suggested by Prof. Wyville Thomson, viz., carbonic acid; yet there may be others." According to his view, however,[131] the genesis of the red clay has been due to the decomposition of feldspathic minerals, detected by the microscope in the ooze, which have been poured into the ocean in suspension by rivers and by atmospheric showers, viz., pumice, feldspar and sanidine, as well as augite, hornblende, quartz, leucite, magnetite, mica and olivine.

However, no experimental proof has yet been presented of the ability of carbon dioxide to overcome, in so short a time, the resistance to decomposition of the chitinous tissue of a recently living shell, and the protection from solution it affords to the enveloped calcium-carbonate. The known feeble influence of carbon dioxide upon the pumice, etc., especially under the conditions of temperature, etc., at the sea-bottom, renders it further probable that the chemical action has taken place *chiefly upon the bottom, within the ooze*, and at an inconceivably slow rate.

Again, nodules[132] have been found abundantly in the red clay, which consist mainly of manganic oxide, in part of ferric oxide. They are "round, oval, or mammillated, and very irregular, varying in size from a grain of mustard seed to a large potato." They possess a concentric structure, with a radiating fibrous arrangement, and "appear to form loose among the soft clay." The corals, otoliths, teeth, siliceous sponges, etc., which are often largely disseminated through this variety of ooze, frequently display a metasomatic alteration into the same concretionary material; and fragments of pumice or other minerals often constitute the nuclei.

Indications of flint,[133] of a somewhat indefinite nature, have been also frequently noticed, apparently occurring only where siliceous organisms were absent. Sometimes it was represented by a siliceous cement, binding together the shells of the ooze, in a gray flinty-like matrix; sometimes by small angular and soft pieces

[131] Proc. Roy. Soc., 1876, XXIV, 531; Voy. of Chall. Atl., II, 253-255.

[132] Thomson and Murray, Proc. Roy. Soc., 1876, XXIV, 39, 464, etc.; Voy. of Chall., Atl., I, 169, 189, etc. Also in Loch Fyne, J. Y. Buchanan, Nature, 1878, XVIII, 638.

[133] Murray, *idem*, 491, 517, 524, etc.

of a cherty-like mineral; and sometimes by a yellow and green siliceous nucleus to the manganese nodules, occasionally presenting agate-bands.

In the bottom of the Pacific, the clay is sometimes found "in a peculiar concretionary state, run together into coherent lumps," or the blue mud has even experienced an induration into large pieces of rock, raised by the dredge, which are "merely hardened portions of the bottom."[134]

§ 31. *Organic matter in the ooze.*— Considerable evidence now exists that a substance corresponding to humus, simply in its yield of acid solvents of lime, oxides of iron, manganese, etc., enters universally into the constitution of the layer of ooze upon the bottom of the ocean. Its exact composition has never yet been determined; but it may be suspected that it resembles that of *glairine* (§ 20), especially in its high content of silica. As it has resulted from the continuous decomposition of the cellulose membranes of the diatomaceæ, etc., and of the gelatinous sarcode of the radiolaria, spongiæ, and foraminifera, which may be there living or deposited by subsidence from the surface, its composition must differ widely from that of the humus of subaërial eremacausis, in its large proportion of water and nitrogen and in its poverty in carbon. It must thus present the most favorable conditions for rapid dissociation.

Concerning the globigerina-ooze, it is said, "the stomachs of the more highly organized animals living in it or on its surface are always full of the fresher foraminiferal shells, from which they undoubtedly derive not only material for the calcification of their tests, but nitrogenous matter for assimilation likewise."[135] Indeed Ehrenberg found long ago that the foraminiferal shells at the bottom of the ocean are "not empty, but are often filled with organic substance;"[136] and a transparent gelatinous matter has been since observed by Huxley, and called *Bathybius*, in the form of innumerable minute lumps, scattered through the ooze, "forming a living scum or film on the sea-bed . . . . so that it probably forms one continuous scum of living matter girding the whole surface of the sea-bed:" and by Mahony, as particles still occupy-

[134] Thomson and Murray, *idem*, 33, 499, 504, 506, 529, etc.
[135] Thomson, Voy. of Chall., Atl., II, 283.
[136] Bischof, *op. cit.*, III, 109.

in the Atlantic, with its 3,000,000 square miles of area. The enormous masses of decomposing vegetable matter in the salt-marshes, continually being leached along the margins of the oceans — in the submerged peatbeds, whose existence has been pointed out[146] along many shores — and in the organic portion of the dust of land-breezes, sweeping far out over the seas, represent other and important sources of this constituent of sea-water. One probable result of the further decomposition, by aeration, of the organic matter in the sea and in the ooze, is the development of carbon dioxide in a proportionate quantity in solution, which is much greater near the bottom of the sea, than at the surface: *e. g.*, by the average of the determinations of Buchanan,[147] 20.7 per cent. at the surface, 26.2 per cent. in the median zone, and 27.9 per cent. in the greatest depths. These bottom waters are therefore found to present the ocean-layer *richest in organic matter*, dissolved and suspended, *in carbon dioxide*, and *in calcium*, and *poorest in oxygen*, over the red-clay areas. Thomson has attributed this abnormal amount of carbon dioxide in the bottom-waters of the South Atlantic to their derivation from the surface-waters of Antarctic regions, in the course of the oceanic circulation; but all the characteristics just stated are exactly those consistent with contiguity to the decomposition of organic matter in the underlying ooze.

§ 33. *Presence of organic acids.*—From this point of view, there are the following reasons to suspect that other organic acids, besides carbon dioxide, may share to some extent in the submarine chemical action now attributed entirely to that gas. First, some of the humus-acids, especially humic and apocrenic, are certainly contributed by the rivers, decaying algæ, and subsided peat-beds and salt-marshes; and in the slow submarine decomposition of the sarcode of organisms, the development of other acids, possibly of this group, certainly of more complex constitution and even in nitrogenized combinations, probably precede and accompany that of carbon dioxide.

Secondly, the submarine concentration of manganese and iron

[146] Along the shores of Great Britain, Lyell, Princ. of Geol., 1874, I, 548–550, and II, 536: around the Irish coast, Jukes, *op. cit.*, 686: at the mouth of the Pará, L. Agassiz, Jour. to Brazil, 1868, 434–5: at Ireland Island, Bermudas, Thomson, Voy. of Chall., Atlantic, I, 298: in the vicinity of New York, D. S. Martin, before N. Y. Acad. of Sci., Nov. 17, 1879, etc.

[147] Depths of the Sea, 498.

peroxides, in the concretions referred to, appears analogous to the exceedingly common sub-aërial process, resulting in the same products, which is certainly being carried on by the more complex acids.

Thirdly, the partial deoxidation and complete solution of the iron silicate out of the "red clay," and its deposition within and without the delicate structure of globigerina as perfect casts, in the form of glauconite, is an operation beyond the powers of carbon dioxide, and corresponds closely at least to the deoxidation and solution of ferrous oxide and silica by azo-humic acids in sub-aërial deposits. The problem, as yet unsolved, in regard to the origin of glauconite, may yet find a satisfactory explanation in this direction, when the exact character and action of the azo-humic acids shall have been more fully understood. Brazier found that the ignition of the ooze,[148] and Buchanan, that of the manganiferous concretions,[149] yielded water "with a strong alkaline reaction," "a property generally possessed by rocks and minerals;" and this property, as elsewhere shown in this paper, pretty certainly indicates always the formative work of the azo-humic acids and the remaining presence of a significant trace.

Again, the ultimate formation of nodules of flint in such deep-sea sediments, illustrated in its completion by the nodules and lenticular layers of that mineral and chert disseminated through all strata of Chalk and other calcareous formations, is generally explained by either of two theories: that the silica is concentrated from the amount existing in the waters of the ocean: or that the siliceous particles, contributed by sponge-spicules, diatoms, radiolaria, polycystines, xanthidia, etc., as well as those of inorganic character, fragmentary crystals, etc., are subsequently aggregated within the sediment: either process having been brought about by a mysterious entity represented by the term, "the force of segregation."

Since the studies of Leopold von Buch on the silicification of shells (Abh. d. K. Akad. d. Wiss., Berlin, 1828, 43) first called general attention to the remarkable way in which the deposit of silica has followed the extension of the organic substance of the animal, and that only, Bischof and most observers have recognized an important but as yet undetermined process of attraction between animal matter and silica. H. Johnson has suggested that

[148] Voy. of Chall., Atl., II, 325. [149] Proc. Roy. Soc., *loc. cit.*, 607-608.

the carbon of animal matter has been directly replaced by silicon; W. J. Sollas (Geol. Mag., 1873, X, 92) supposes that "when silicic acid is added to such animal matters as albumen or gelatin, it forms with them a definite chemical compound," from which it may be afterwards separated during decomposition. These theories require the introduction and addition of silica, necessarily from solution in the sea-water, to the organic matter in place. I would therefore modify Sollas' theory by suggesting that *during the decomposition* of the sarcode of both animal and vegetable organisms, after death, gelatinous or colloid substances are generated, resembling *glairine*, which are soluble in sea-water, which combine with silica and may therefore convey and concentrate it, dissolving its particles disseminated through submarine sediments, and which may in certain forms, produced by gradual oxidation, act also as acid solvents of lime, oxides of iron and manganese, etc. To this idea, in part, an early opinion of Bischof approaches: "silicifications are nothing else than the result of combinations between the crenic acids (quellsaüren) formed through decomposition of organic matter, *e. g.*, of mussels and oysters, and silica which, in aqueous solution, *e. g.*, as the water of springs, comes in contact therewith." (Erd. Jour. f. pr. Ch., 1834, II, 70–72.)

Now the globigerina-ooze has been found[150] to contain from about four to over twenty per cent. of silica, and the "red clay" up to 54.9 per cent., about half the quantity being in the soluble form. The established solubility of silica in solutions of the azohumic acids therefore suggests that, during the consolidation of the deep-sea sediment, such a solution of disseminated silica by albuminoids and by acids of this character is constantly in progress: that these solutions settle slowly into shallow basins, flow into fissures, and even percolate sluggishly below, along porous layers, generally perhaps submarine basins and subterranean layers in which organisms yielding siliceous particles may predominate: and that as the complex organic combination, probably resembling a lime-salt of a silico-azohumic acid, is dissociated by further oxidation, the dissolved silica is deposited in colloid condition over the surface of the basins, within the fissures, or below, along the drainage planes, around the undissolved siliceous organisms or particles as nuclei, or within the cavities of calcareous organisms during or subsequently to the removal of their calcium-

[150] Buchanan, Voy. of Chall., Atlantic, II, 315–325.

carbonate. The amount of silica in solution in the sea-water seems entirely inadequate to account for such silicification, as suggested by some authors, nor is the process evident; while the frequent association of oxide of iron with silica, in such submarine replacements, appears to be an additional indication of the character of the solvents and process, as just described.

I find, therefore, the chemical reactions in progress within the submarine ooze-layer so similar in their results to those commonly observed in sub-aërial unconsolidated deposits (*e. g.*, the Tertiary and Cretaceous sands of New Jersey), that I am inclined to assign both to substantially the same solvent agency—that of *acids produced by organic decomposition*. There is but a single agency which on land is constantly producing the solution and concentration of ferric and manganic oxides, as well as of silica itself, and the cementation of sands by one or more of those three substances; a similar agent shows its presence and action by analogous results beneath the sea.

Only one material difference is apparent, that of the predominance of manganese over iron oxide in the concretions of the ooze, in that superficial layer within the reach of our investigation. The explanation is found, I think, in the *solvent action of sea-water*, as shown by its composition. In 1000 parts of sea-water, various analysts have found 0.0019 and 0.0022 ferrous carbonate in the North Atlantic Ocean, 0.005 in the Irish Sea, 0.0029 to 0.0065 in the Indian Ocean, etc.;[151] but *not even a trace of manganese* has yet been reported. May we not thence suppose, that, during the ages of the slow increment of the abyssal ooze, a constant solution and removal of the iron oxide has been carried on by the sea-water, out of the superficial layer, while the greater part of the manganese has merely been concentrated, peroxidized, and rendered insoluble?

Action upon Solid Rocks.

§ 34. *Superficial decomposition.*— The *superficial* effects upon rocks of the corrosive action of acids, derived from decomposing vegetation, will not now be discussed. It is sufficient here to state my conviction that these effects, everywhere apparent upon naked surfaces of rocks, even when vertical, have been due, to a far larger extent than usually believed, to the initial and long

[151] Roth, *op. cit.*, 505–531.

continued action of cryptogamous vegetation, especially that of the lichens and mosses; not so much perhaps by the direct action of the organic acids within the living tissues, as by those of the films or layers of humus underlying the encrusting sheets of these plants.

To these acids may be attributed also, to a greater or less degree, the excavation of shallow basins on horizontal surfaces, the loosening and separation of blocks of rock along the face of ledges, etc. At present we will proceed to consider the more profound effects of the same solvent agencies.

Even in those rocks in which alteration has been strongly resisted by their structure, *e. g.*, fine texture—by absence of lamination, fissures and cavities, *e. g.*, in many of the more compact eruptive rocks, possessing a glassy base—or by their chemical composition, such as the absence of soluble or unstable constituents, *e. g.*, the aluminous argillytes, siliceous sandstones, etc.—there is universal evidence of a deep and extensive decomposition. No quarry, mine, boring, or artificial excavation of any kind has yet been made to a depth which limits the progress of this alteration, at least along the most continuous and empty fissures. And wherever those minerals are abundant which are rich in soluble bases, *e. g.*, hornblende, chlorite, augite, etc., and particularly those which are unstable, *e. g.*, the metallic sulphides, there the decomposition is notoriously extensive, and affects and accelerates, by a kind of contact action, that of other constituents in which its progress would be otherwise slow. The waste material on the dumps of any mine presents a striking illustration of the rapidity of the last instance mentioned.

X. Erosion of Limestones.

§ 35. *General erosion and excavation.*—The ready solvency of limestone, even in carbon dioxide, has led to far more extensive and conspicuous results of erosion than those produced in most other rocks; and these have long been the subject of investigation by all geological observers. It has been pointed out that even "in the sea, vegetation carries on a slow degradation of the sides. Especially must it deeply corrode calcareous rocks."[152] Certainly, on the land, many of these results may be attributed in large part

[152] M. Delesse, Lithologie du fond des mers, 1871.

to other organic acids, derived even from living vegetation. "We frequently find in meadows smooth limestones with their surfaces covered with a network of small furrows. When these stones are newly taken out of the ground, we find that each furrow corresponds to a rootlet, which appears as if it had eaten its way into the stone."[153]

The action of many acids, produced by decomposition, are surely concerned where bogs, rich soils, and similar accumulations of humus, rest directly upon a limestone-stratum. The general erosion this material has experienced,[154] in regions of abundant vegetation, is shown, even superficially, by deep pitting, gulleying, the removal of vast quantities of material, and, as Bischof long ago pointed out, the sinking of strata. The action has probably begun by the vertical sinking, both of a humus-bed and of its drainage-ways, into its easily soluble foundation, accelerating by the same process the work of mechanical corrosion. When an excessive amount of calcium-carbonate has been thus brought into solution—as when, in the tropics, a stream, overhung by dense vegetation, flows over coral rock—it may be constantly deposited upon the bed of the stream in the form of ridges and projections, enclosing basins.[155]

The joints and more irregular fissures which abound particularly in limestone-strata, have also been the seat of enormous erosion and widening into subterranean passages and caverns, chiefly by a chemical solution of their material, which has been mainly effected by carbon dioxide; though, during and immediately after heavy rains, the other humus-acids must have taken their part in this action. The excavation of caverns in the Sub-Carboniferous limestones, and the deposit within them of stalactitic limonite ores, "by the dissolving action of acid waters," "probably containing carbonic acid," has been largely discussed, for Missouri, by Dr. A. Schmidt and P. N. Moore (Geol. Surv. Missouri, 1872, 127, 640–1, and 1873–4, 405), and for Alabama, by E. A. Smith (Rep. Geol. Surv. Ala., 1879, 15).

[153] J. Liebig, Modern Agric., 43.

[154] See the work of T. Mellard Reade on "Chemical denudation in relation to Geological Time," 1879. Also his paper on "Chemical Action in its geological aspect," Hardw. Sci. Goss., 1879, 6. The agency there considered is merely "the chemical action of rain."

[155] At Wokan Island in the Pacific, Mosely, *op. cit.*, 378; in Roaring river, Jamaica, De la Beche, Geol. Obs., 13.

Lesley has made careful study[156] of these caverns, in the Lower Silurian of Pennsylvania, with special reference to the following points: the support of the roof by the union of stalactites and stalagmites: the occupation of the caverns by clay, as a residue from the solution of the limestone: the metasomatic alteration of the stalactitic pillars into limonite (pipe-ore): and the letting down of the overlying beds and modification of the superficial topography.

The nature and extent of that alteration and of its significant product, limonite, suggest the associated action of other organic acids which are quicker and better solvents, both of calcium-carbonate and of ferric oxide, than carbon dioxide.

§ 36. *Extensive denudation.*—The most impressive illustration, however, of the vast power of these apparently feeble agencies, working quietly through long periods of time, is shown in the enormous denudation they have effected by chemical solution of calcareous strata over extensive areas.

Bischof gave the first full explanation of the results of this solution, in the formation of caverns and in the concentration of the comparatively insoluble impurities of limestones: *i. e.*, the production both of dolomytes,[157] by concentration of the feebly soluble magnesian constituents—of clays,[158] by the accumulation of siliceous residues—and of iron-ores,[159] by the concentration of iron-oxides. J. D. Whitney has observed, in the lead regions of Wisconsin,[160] a layer, averaging ten feet in thickness but sometimes reaching thirty feet, consisting of soil, sandy loam, and a red clay abounding in fragments of chert and galena or of undissolved limestone, resting upon a bed of that rock whose "surface is uneven and irregular, bearing the marks of chemical rather than of mechanical erosion." This layer Whitney considers to be the residuum left after the gradual solution, "by the simple agency of rain," of beds formerly extending over the whole region, some 350 to 400 feet in vertical thickness, of impure limestones, containing two to ten per cent. of insoluble matter and one or two per cent. of ferrous carbonate, as well as, in part, of cherty limestones and calcareous shales. The excavation of river valleys to a very considerable width and depth, throughout the same district, are considered attributable to the same agency.

[156] Geol. Mag., New Series, 1879, VI, 459. [157] *Op. cit.*, III, 180-202.
[158] *Idem*, 193-4. [159] *Idem*, 337-340. [160] Geol. of Wis., 1862, I, 117-126.

This process has been observed on a much larger scale among the dolomites of southern Missouri,[161] where it has produced, since the close of the Carboniferous period, "residuary deposits" of great economic importance, consisting of iron, lead, and zinc-ores.

Vast masses of a chert-breccia have been thus formed in Missouri, etc.; in Belgium also, near Dinant, etc., Dupont states that blocks of the "Pthanite" have been left, abundantly scattered upon the soil, by the more rapid solution and removal of the limestone (Bull. de l'Ac. roy. de Belge, (2), X, Nos. 9 and 10).

In England, Tertiary white clays have been observed, occupying pockets in the Carboniferous limestone (and elsewhere also derived from the Chalk), which contain the silica and alumina in the same proportions (2 to 1) as in the impurities of the limestone. It is therefore concluded that "they were left behind in the cavities after the calcareous matter had been removed by watery dissolutions" of carbon dioxide.[162] At Buxton, partially dissolved fragments of limestone occur beneath the thin covering of turf.[163] Argillaceous limestones, containing ferrous oxide, are thus often converted into "rotten stone" by the removal of calcium-carbonate, etc.[164] Similar examples occur abroad which I would refer to a corresponding concentration of the metallic oxides diffused through impure limestones. In the smithsonite and galenite deposits of the Muschelkalk formation of Upper Silesia and Poland, the following succession of beds commonly rests upon the dolomyte: 1, Surface soil — 2, Tertiary sand and clay — 3, Yellow Clay — 4, Limonite — 5, Clay — 6, White smithsonite, thirty inches to fourteen feet in thickness — and sometimes, 7, Galenite, in the dolomyte near smithsonite, or in pockets of the overlying beds. Beneath these, "the strata of the floor-limestone, which generally lie horizontally, frequently have their upper surface not parallel to the stratification, and *it appears as if eaten by acids*, so that fossils, and some harder ledges of the strata, are prominent."[165] Von Cotta recognizes a certain analogy between the formation of the limonite in the zinc-ore deposits and that of bog iron-ore. The formation of the zinc-ore he attributes to weak

[161] R. Pumpelly, Geol. Surv. of Missouri, 1872, 9–13, and 1873, 8.
[162] G. Maw, Geol. Mag., 1867, IV, 420.
[163] "The waste of rock masses by solution," E. Brown, Geol. Mag., 1869, VI, 379.
[164] J. B. Jukes, Student's Man. of Geol., 1862, 158.
[165] Von Cotta, *op. cit.*, 248, 256.

zinc solutions re-acting on the dolomitic limestones; but the very analogy to bog-ores, referred to, seems to indicate that the solution of the zinc-oxide itself has been caused as well by the action of one or more of the same organic acids.

Besides this action of denudation, it has even been suggested that the metamorphism of sedimentary limestones into the crystalline condition has been, in Brazil, produced "by soaking with meteoric waters."[166]

It has also been noted that a decoloration, produced by the same agency, has affected the gray and yellow dolomytes and limestones of the upper Silurian in Livonia, etc.[167]

XI. Porous Sedimentary Rocks.

§ 37. *Saturation of porous masses.*—In the examples of decomposition just discussed, reference has been made only to those rocks whose density is so great as to resist the passage of waters, to any considerable extent, except through fissures or along those porous planes of stratification in which the constituent grains are aggregated more loosely or by a more soluble cement. But enormous masses of rock occur, chiefly sedimentary, whose material is itself decidedly porous and has afforded opportunity for considerable movement of infiltrating waters through the mass as well as through its division planes. In this connection there is great importance in the experiments of Barry, Delabeche, Smith in 1839, and later D. T. Ansted,[168] T. S. Hunt,[169] and C. Lang,[170] on the porosity of rocks. The calculations of Ansted and Hunt on the vast quantities of liquid which can be held in the pores of all common sedimentary rocks, have a new and special application to their frequent actual content of, and perhaps occasional saturation by weak solutions of the organic acids, during elevation above the sea-level.

An excellent illustration of the results of such a saturation of a porous mass is shown in the sedimentary sandstones. In these, however, the influence of organic acids is shown in two ways, which need to be clearly distinguished. First, in the degree of the purification of their original materials, before consolidation,

[166] C. F. Hartt, Geol. of Brazil, 280.
[167] Schrenk, Arch. f. naturk. Liv., etc., (1), I, 24.
[168] Chem. News, 1860, II, 223.
[169] Essays, 104, 164.
[170] Zeitschr. f. Biol., 1876, XI, 313-340.

from all soluble and decomposable substances; this has been already partially considered, in reference to the beach-sand deposits of the present Atlantic coast, and is further discussed in the historical review in the closing section of this paper. Secondly, in the solution, transport, and frequent concentration of their interstitial matters by meteoric waters infiltrating downward from the present land-surface. The principal sandstone formations will now be considered in historical order, with reference merely to this latter method of chemical alteration.

The dunyte-beds of North Carolina, which I regard merely as slightly altered sediments — as it were, metamorphic sandstones — made up chiefly of olivine grains, have presented, by their ferrous constituent, a material accessible to an extensive decomposition which will be hereafter described.

§ 38. *Silurian sandstones.*— When almost entirely siliceous, both in their grains and their cement, like those of the Silurian, there was little opportunity for decomposition, except in the few scattered grains of feldspar. The only results are comprised in the kaolinic cementation of certain layers, the concentration of ochreous deposits in others, the decoloration of the more quartzose and porous layers, the general dissemination of more or less opaline silica in the form of cement, and the consequent mottling of the rock in cross-section by irregular stripes and spots of red and white. All these forms of recent decomposition are well shown in the Potsdam sandstones of northern New York, the lithologically similar sandstones of the pre-Silurian tract along the southern shores of Lake Superior, the finer grained grits of the Shawangunk conglomerate which caps the ridge of the mountain of that name in New York, and the similar grits of Lookout Mountain in Tennessee.

The St. Peter's sandstone of Wisconsin exhibits a remarkably mottled coloration in brown and white, and the ferric oxide is often so concentrated that "in the upper part of the formation, irregular concretions of iron-ore occur;" and in some places the ochres of this sandstone are separated by crushing and washing for paint.[171]

In Minnesota, the rock appears to have been originally a purely siliceous sand, very feebly cemented; and its present

[171] T. C. Chamberlin and M. Strong, Geol. of Wis., 1873–77, II, 286, 723.

ferruginous bands and mottling appear to have been subsequently produced by local percolation of ferruginous solutions.[172]

The "Pictured Rocks," of the sandstones along the southern shores of Lake Superior, also present a familiar illustration of lateral exudations, produced by this form of chemical action.

§ 39. *Devonian Sandstones.*—The Devonian sandstones and flags, as represented in the interior of New York, I find to consist chiefly of angular to sub-angular grains of quartz and feldspar, with their interstices occupied by smaller grains of magnetite, scales of chlorite, and particularly short fibres of hornblende interlacing the grains of the other constituents. The result is an "argillaceous sandstone," flagstone, or greywacke, peculiarly compact and impermeable, which has retained its fresh condition to an extent which could not otherwise have been expected from an aggregate of substances so liable to ready decomposition. Nevertheless the impure greenish sandstones of this character which form the bulk of the Catskill Mountains, notwithstanding their general fine texture and density, display a decomposition of the mass and oxidation to a brownish tinge, sometimes to the depth of over two feet.

In England, Young[173] has found the cement of the Old Red Sandstones to contain from six to twenty-six per cent. of calcium-carbonate; and it would seem probable that such a calcareous cement, common both in the Devonian and Carboniferous sandstones, may have been derived, at least in part, from infiltration from overlying limestones or from the decomposition of enclosed silicates, in either case partly effected by percolating solutions of the humus-acids.

§ 40. *Carboniferous Sandstones.*—The cream-colored sandstones of the Sub-Carboniferous, largely quarried as a building stone and exported from Nova Scotia, contain, in addition to quartz, a considerable amount of the feldspars in small angular grains, kaolin, iron-ochre and a little chlorite in minute scales. The more readily decomposed constituents, which in general can be distinguished only on a microscopical examination of thin sections of the rock, are effectually protected from attack by meteoric waters, in part through their fine grain and close aggregation, but chiefly through the kaolinic powder which completely fills up their interstices with

[172] N. H. Winchell, Geol. and Nat. Hist. Surv. Minn., 1876, 146.
[173] J. Wallace Young, Chem. News, 1868, III, 307.

a compact almost impervious cement. To this are due the fresh condition and almost uniform cream-color of the quarried rock, as well as its excellent and long continued resistance, when exposed to the weather, to decomposition and discoloration.

The ferruginous sandstones of the Carboniferous may be included in the discussion, below, of their lithological equivalents of later age.

§ 41. *Mesozoic Sandstones.*—A microscopical and chemical examination of the brown freestone from Portland, Connecticut, reveals the following components: quartz, largely predominating in clear sub-angular grains: orthoclase, muscovite, and ochreous ferric hydrate:[174] occasional particles of plagioclase, hornblende and magnetite, and scales of chlorite: and a constant though very small amount of amorphous calcium-carbonate.

Near the plane of contact with the overflows of diabase, which form a conspicuous feature in this horizon, in the form of the well-known trap-dykes of Connecticut, New Jersey, etc., the metamorphism has been so general and profound that often, though not always, the contiguous layer of sandstone, to the depth of five to ten feet, has been converted into an indurated arkose, black "trappean schists," or an actual feldspathic quartzyte, in which the cement often consists of opaline silica, as shown by careful analyses.[175] Such compact varieties of course have experienced little decomposition except superficial and kaolinic, by the passage of meteoric waters. But the predominant variety of this rock, that which is extensively exposed in the quarries of Connecticut and New Jersey, affords, I think, unmistakable evidence, in many strata, of the passage of percolating solutions of aerated and carbonated waters, and probably of the acids of organic decay, attended by the attack and partial decomposition of certain constituents of the rock. The nature of the decomposition is shown, in the thin sections, especially by the grains and scales of chlorite, biotite, hornblende, etc., in all stages of ochreous alteration; and to this may be *partially* attributed the abundance of reddish ochre which fills up all interstices. The chlorite is probably prochlorite, a mineral which, as already shown in Bolton's

[174] Cook reports three per cent. of ferric oxide and four per cent. of alumina in one specimen examined (Rep. Geol. N. J., 1863, 509).

[175] H. Wurtz, Proc. N. Y. Lyc. Nat. Hist., 1870, 99–105. P. Schweitzer, Am. Chem., 1871, July.

table (§2), is readily decomposed in the cold by the action of citric acid.

§ 42. *Decomposition of organic remains.*—The subterranean oxidation and decomposition of vegetable remains, within strata of all formations, is also an important mode for the internal development of organic acids. Illustrations of this fact are abundant and well known. Prof. D. S. Martin has observed, at Newark, N. J., masses of Triassic sandstone, in which vegetable remains plentifully occur, bleached to greenish-yellow and light-gray. A similar reduction and change of color in large masses of the rock have been observed by Profs. H. C. Bolton and A. H. Chester, in the quarries at Portland, Connecticut; the Silurian sandstones along the shores of Lake Superior are often peculiarly spotted and mottled in this way; and in many of these cases nuclei of organic matter may be detected near the centre of the lens or sphere of bleached rock. The same fact is of common occurrence in the layers of the Devonian and Carboniferous sandstones which contain carbonized plants, fishes, etc., in central New York and elsewhere. In such cases the solvent action of organic acids is probably in progress, such as the carbo-ulmic and carbo-humic acids of Herz (*vide ante*), derived from lignite; in fact, Reichel has reported both bituminous resin and ulmic acid, in his analysis of the cement of a sandstone from Saxony.[176]

All loosely aggregated and porous sandstones exhibit the same results from infiltrating acid solutions.

The Triassic sandstones largely quarried in the vicinity of Heidelberg, in Baden, I found to display the same concentration of iron-ochre, often to a degree not usual in American localities, in large bunches which were sometimes almost pure limonite-ochre; a similar concentration of iron-oxide in streaks, powder, etc., has been observed in the Carboniferous sandstones of Missouri (Geol. Missouri, 1873, 42).

Action upon Slates.

§ 43. *General softening.*—From the chemical composition of argillytes and other crypto-crystalline schists, they have offered a remarkable resistance to the chemical action which has caused the decay of other rocks. Of course this resistance has been prob-

[176] Bischof, *op. cit.*, III, 99.

ably due in large part to their fine texture and impermeability. The decomposition effected is ordinarily shown by a softening to a pulverulent clayey mass, still retaining the schistose structure, and an oxidation of protoxides, indicated by the passage of the hard blue and green argillytes into softer clay slates and shales. Familiar examples of this disintegrating action occur on all slate-terranes, *e. g.*, in this country, in Vermont, North Carolina, the Huronian areas of Michigan, Wisconsin and Canada; and its comparatively shallow depth, rarely over ten or fifteen feet, has often enabled these soft rocks to project in ridges and swells, in defiance both of glacial excavation and recent erosion.

In many cases, also, the green mottling of the hard blue roofing-slates appears to be one of the deeper-seated later effects, of secondary origin, brought about by an alteration of the condition of oxidation of the iron-oxides by percolating acid solutions.

§ 44. *Red Shales.*—Again, there is some reason to believe that the rock of the Catskill formation, in the Catskill mountains of New York, styled the "red shale," should more properly be called the "green shale." The original color and condition of oxidation, still retained in the underlying mass, seemed to me to be occasionally revealed in fresh excavations by streams or artificial means, at many points in the vicinity of the Kaaterskill Clove, and even along the road on the ascent to the Mountain House. The term generally accepted seems to be an instance of the erroneous conclusions and names which have been often founded upon the visible characteristics of the superficial and decomposed crust of a rock; in fact in many regions, the true lithological character of certain strata, entirely unaffected by decomposition, has never yet been seen, or perhaps only in artificial shafts of extreme depth.

The deposit of red clay which deep-sea exploration has revealed over the ocean bottom off the coast of South America, and which the naturalists of the Challenger attribute to the silt of the large rivers of that continent, illustrates the conditions of the formation of the red silt, containing the iron in peroxidized state, which constitutes the coloring material of Triassic sandstones and red shales. But, in general, sufficient organic matter has been intermingled with such silt deposits to reduce most of their free iron-oxide, very soon after consolidation, to the ferrous state. And

in the Catskill formation, a comparatively impermeable cap has been supplied, for protection from later alteration, by the conglomerates and remarkably compact flags which overlie and are interbedded with the shales. In the flags, the oxide of iron of the detrital ingredients is largely in a ferrous condition, and the rock is green, which is everywhere apparent because the "weathering" has penetrated but one or two feet into the compact material. This alone would create a presumption that the finer sediments, now represented by the shales, must have been originally of the same character and color; and their thin lamination has caused the shales to be affected by a deeper decomposition (often fifteen or twenty feet) than the more compact associated flags. Again, in the red crust of these green shales, a subsequent return of the iron to the ferrous condition is often shown, in the Catskills, by a green veining and mottling, sometimes of an extensive character, in strong contrast with the red color of the shale. On close examination it is always found to be connected with or intersected by the natural joints and fissures of the rock, and may be certainly attributed to the reducing effect of solutions of organic acids, percolating through the joints from the rich humus-layer which clothes the sides of the mountains. This green variety of shale of recent origin seems in general to be easily distinguished from the green color of the unaltered underlying rock by the peculiar brightness and shade of the green color.

A similar alteration has been noticed in some of the hematitic phyllytes of Belgium, which carry the layers of garnetiferous honestone (coticule).[177] The margins both of the natural cleavage-joints and irregular fissures are softened and bleached to a yellowish-white color, to the width of several millimeters up to one centimeter. The action has been attributed to "atmospheric agents" in percolating waters, washing the carbonaceous coloring particles out of the slate and converting the hematite into limonite. Reference may here be made to the spotting, often regular and producing a beautiful effect, which is sometimes seen, both in red shales (as at the "Red Chasm" in the Kaaterskill Clove), and in the green slates of Vermont and the green Cambrian slates of Wales.[178] This seems to originate from nuclei, sometimes of or-

[177] A. Renard, Mém. sur le struct. et la comp. min. du coticule, 1877, 39, note.
[178] G. Maw, Geol. Mag., 1869, VI, 576.

University of MICHIGAN

ganic matter but sometimes of pyrite, and may not always have connection with the organic agents now under discussion.

XIII. Disintegration of Crystalline Rocks.

§ 45. *Deep decomposition.*—It is a fact of universal observation that crystalline rocks in place, whose denuded surfaces are covered with a weathering crust, rarely exceeding two or three inches in thickness, present internal evidences of decomposition to a great depth, in some cases even several hundred feet. The seams of stratification, slaty lamination, joints and irregular fissures, are lined or nearly filled with ochreous and generally pulverulent deposits of the hydrates of the various higher oxides of iron and manganese. Within ten to fifty feet of the surface, even those rocks, which at first glance appear compact and fresh, reveal on closer examination, astonishing evidences of their permeability and of the corrosive agency of infiltrating meteoric waters. Perhaps that class of rocks, both crystalline and sedimentary, in which orthoclase is a common constituent, and which cover a large extent of the earth's surface, presents the most conspicuous illustration, on the one hand, of apparent compactness, impermeability, and apparently favorable conditions for resistance to decomposition, and, on the other, of the indubitable evidences of profound and often extensive change. For example, the Montalban gneisses of even our northern states present these evidences in a remarkable degree. In an ordinary specimen of the micaceous gneiss, poor in feldspar, abundant on New York island, taken from a depth of about ten feet and apparently but slightly altered, on a section across the lamination from ten to twelve ochreous seams were counted to the inch, each covered by a mere film of the reddish ferric hydrate, but so thin and inconspicuous, as to be hardly visible except where the fracture ran obliquely across. On digesting the powdered rock in dilute hydrochloric acid, I was surprised to find that it yielded 7.71 per cent. of ferric oxide; so that taking five per cent. as the average, in every 100 cubic metres (130 cubic yards) of this rock the amount of 13.5 metric tons (13.2 English long tons) of ferric oxide, or 9.45 metric tons (9.3 English long tons) of metallic iron, is on its way to lower drainage-levels: either to pass into the river and bay, and so into the ocean, or, as the conditions of the topography shall determine, to be arrested in some glacial rock-basin and

marsh, in the form of beds of bog iron-ore, usually manganiferous. And large beds of this ore were found in abundance in the bottoms of the valleys, on the first settlement of Manhattan island.[179]

§ 46. *Various theories.*—The disintegration of granyte (maladie du granit) has long ago been considered by Dolomieu and attributed by him to the action of carbon-dioxide evolved from subterranean vents. Darwin[180] first called attention in 1851 to the remarkable extent of this decomposition, as shown in Brazil, but suspected that it had taken place during submergence beneath the sea. Heusser and Claraz suggested[181] that the agent was "the dissolving action of water, which increases with the temperature," aided by some nitric acid derived from the atmosphere. Agassiz[182] considered that the disintegration of rocks in the tropics had been effected by "the warm rains falling upon the heated soil." T. Sterry Hunt[183] called attention to the depth and extent of this disintegration, in all the crystalline schists of the southern United States and of Brazil, and assigned its cause to the influence of "the peculiar composition of the atmosphere, in early times," especially when rich in carbon-dioxide during the Carboniferous period. Hartt, in his careful study of the phenomena in Brazil,[184] assigns the cause to warm rain-water, carrying carbon-dioxide both from the air and from vegetation decaying upon the soil, "together with organic acids, nitrate of ammonia, etc." He also states his belief that the alteration occurs only in regions anciently or at present covered by forest. Further observations have been contributed by J. D. Dana on the Pacific islands and South American coast,[185] Pumpelly in China,[186] Missouri,[187] etc., L. S. Burbank in North Carolina,[188] Dr. Benza in Hindostan,[189] Le Conte on the general subject,[190] and many others. I hope hereafter to present a further discussion of the phenomena as exhibited in North Carolina. It is sufficient for my

[179] Mather, Nat. Hist. of N. Y., 1843, IV, I, 120.
[180] Geol. Obs., Ed. of 1876, 427–8.
[181] Ann. d. mines, (5), Mém., 1870, XVII, 291.
[182] Letter of 1865. Jour. to Brazil, 1868, 86–89.
[183] Chem. and Geol. Ess., 1871–1873, 2, 10, 20, 41, 101–3, 250.
[184] Geol. and Phys. Geog. of Brazil, 1870, 24.
[185] U. S. Expl. Exp., Geol., 1846–9, 298, 513, etc.
[186] Smiths. Inst., 1866, 72, 73, 26.
[187] Geol. Surv. of Missouri, 1873, 8.
[188] Proc. Boston Soc. Nat. Hist., 1873, XVI, Nov.
[189] Madras Jour. of Lit., 1836, 246.
[190] El. of Geol., 4.

present purpose to state that this action may be attributed simply to the effect of the abundant vegetation which formerly clothed the surface of that state, and which probably rested, as it now does in the mountains of the western part, upon a thick and rich black layer of decomposing humus. So that, both in Brazil and in our southern states, the main agents of disintegration have been mainly derived, I believe, from neither atmospheric nor subterranean sources, but from the heavy primeval forest-growth which preceded the inroads of our present civilization. And of these agents carbon dioxide has been but a single, and, in the *superficial* work of chemical erosion, a subordinate member.

In the satisfactory hypothesis, recently advanced,[191] in regard to the secular rock-disintegration which preceded the excavation of rock-basins by wind, water, or ice, especially in post-Tertiary times, attention was called to the relationship of the character and degree of the alteration to the chemical composition of the material of the rock itself: the property of resistance to carbon dioxide having determined the survival of a mass, rather than the property of hardness which chiefly controls the extent of mechanical erosion. If, however, in addition to the "carbonic acid, water, and free oxygen" to which the author refers the disintegration, the agency of complex organic acids, having a solvency for silica, has been concerned, as now suggested, it might be expected that an alteration by such agents will be shown by a depth and character of products depending upon the solvency, and ready susceptibility to chemical decomposition, of the *silicates* of the crystalline rocks. This will depend therefore not entirely, often not even chiefly, upon the action of carbon dioxide, and can affect not merely the feldspars, but, as we actually find, all silicates without exception. The degree of the decomposition, however, varies greatly with the chemical nature of the rock: so that, as Pumpelly has pointed out, glacial action has been compelled to spare projecting ridges of even such materials as the soft clay slates and mica schists.

Prof. W. C. Kerr has verbally described an interesting example in North Carolina, with which I have also been impressed, of the remarkable contrast between the deep decay and disintegration of the crystalline rocks of the "Greensboro belt," *e. g.*, gneisses, diorytes, greenstones, etc., stretching across the state from north-

[191] R. Pumpelly, Am. J. Sci., (3), 1879, XVII, 133.

east to southwest, and the thinly disintegrated or even almost naked surface of the aluminous slates of the parallel belt on the east; though even in the latter a decomposition to a great depth is usually shown by their alteration from hard blue or green argillytes to softened and ferruginous clay slates.

XIV. Theory of Subterranean Decomposition.

§ 47. *Principal agents.*— What has been the agency to which we must attribute the decomposition of minerals, as well as the transport of their products, in such enormous quantities? We can not look upon carbon dioxide solely, and, it is probable, not even chiefly, as the *attacking agent:* though it may have served as the main *vehicle for transport* of the decomposition products. It can not even dissolve the iron-oxide, except in the ferrous condition; soluble humus-substances, it may be in the simplest forms, ordinarily called "amorphous," must serve for the previous deoxidation of ferrous silicates; this very process is synonymous with the oxidation of the organic matter to the more complex forms, which are the acids mainly under discussion, and still exert strong reducing power; and finally, these acids possess far greater efficiency for corrosive attack than carbon dioxide, in their far greater solvency of all the iron-oxides and other bases, as well as of the silica therewith associated.

Messrs. W. B. and R. E. Rogers have shown (Am. J. Sci., 1848, (2), V, 401), in a brief statement of their experiments on a series of about thirty-six minerals and rocks, that carbonated or even simple water exerts an appreciable effect in their decomposition; and that, with the magnesian and calcareo-magnesian silicates, *e. g.*, hornblende, chlorite, etc., an amount of 0.4 to 1 per cent. may pass into solution, by prolonged digestion in carbonated water. On these grounds the natural solutions of "carbonic acid, water, and free oxygen," have been the agents invoked by Ebelmen, Detmer,[192] Boussingault,[193] Pumpelly, and most authors, to account for the forms of enormous chemical erosion, just described. However, the more definite experiments of Beyer[194] have an important significance, in opposition to this conclusion. On treating one kilogramme of finely-ground feldspar with two and one-half

[192] *Loc. cit.*, 249.
[193] *Loc. cit.*, 397.
[194] Dr. A. Beyer, Die Landw. Vers. Stat., 1871, XIV, 314–322.

litres of water and of various saline solutions, during about twenty-nine months, he obtained results of which it is sufficient here to quote the extremes. The amount, in grammes, of the constituents of the feldspar found dissolved in each solution, was as follows: —

Distilled water	0.29,	solution of gypsum	4.92,
aerated water	0.19,	solution of magnesia	8.29.
carbonated water	0.39,	and carbon dioxide	

He therefore concludes that carbon dioxide and aerated water have exerted, during this period of the experiment, no essential effect.

The conditions of the process of subterranean decomposition of rocks, by the humus-acids, now in progress, therefore appear to be intermittent, and to depend upon the character and thickness of the superincumbent layer of soil: upon the climate and season of the year, as determining the amount of rainfall, the temperature of the soil and of the meteoric solutions, and the nature and extent of the process of eremacausis in the humus: and upon the abundance, width, slope, extent, amount of obstruction, freedom of drainage, and duration of dryness, in the capillary fissures, pores, or wider cavities in the subjacent mass of rock.

§ 48. *Three zones.*—In the ordinary conditions of those strata, under our observation, which are elevated above the sea-level and freely drained, three vertical zones of chemical action, produced largely through these acids, may be distinguished.

The highest zone, next to the surface, is constantly subjected to the action of all the acids of humus, as well as atmospheric waters; and in this the most extensive and continuous process of corrosion and solution is going on. It is probable that its depth in our climate, during the summer, rarely exceeds ten to twenty feet, but must be actually very variable, ranging from a few inches, during excessive droughts, to at least hundreds of feet, during long continued rains. And with the heavy rains of autumn, the continuous saturation of the subterranean strata during the winter, and the thawing of snows, the floods, and the frequent showers of spring, a large part of the soluble matters of humus must be leached out of the soil, to find its way in part and to extend the process of corrosion of the rock and transport of its soluble constituents to still more profound depths.

Next below comes a median zone, into which, during an ordinary

east to southwest, and the thinly disintegrated or even almost naked surface of the aluminous slates of the parallel belt on the east; though even in the latter a decomposition to a great depth is usually shown by their alteration from hard blue or green argillytes to softened and ferruginous clay slates.

XIV. Theory of Subterranean Decomposition.

§ 47. *Principal agents.*— What has been the agency to which we must attribute the decomposition of minerals, as well as the transport of their products, in such enormous quantities? We can not look upon carbon dioxide solely, and, it is probable, not even chiefly, as the *attacking agent:* though it may have served as the main *vehicle for transport* of the decomposition products. It can not even dissolve the iron-oxide, except in the ferrous condition; soluble humus-substances, it may be in the simplest forms, ordinarily called "amorphous," must serve for the previous deoxidation of ferrous silicates; this very process is synonymous with the oxidation of the organic matter to the more complex forms, which are the acids mainly under discussion, and still exert strong reducing power; and finally, these acids possess far greater efficiency for corrosive attack than carbon dioxide, in their far greater solvency of all the iron-oxides and other bases, as well as of the silica therewith associated.

Messrs. W. B. and R. E. Rogers have shown (Am. J. Sci., 1848, (2), V, 401), in a brief statement of their experiments on a series of about thirty-six minerals and rocks, that carbonated or even simple water exerts an appreciable effect in their decomposition; and that, with the magnesian and calcareo-magnesian silicates, *e. g.*, hornblende, chlorite, etc., an amount of 0.4 to 1 per cent. may pass into solution, by prolonged digestion in carbonated water. On these grounds the natural solutions of "carbonic acid, water, and free oxygen," have been the agents invoked by Ebelmen, Detmer,[192] Boussingault,[193] Pumpelly, and most authors, to account for the forms of enormous chemical erosion, just described. However, the more definite experiments of Beyer[194] have an important significance, in opposition to this conclusion. On treating one kilogramme of finely-ground feldspar with two and one-half

[192] *Loc. cit.*, 249.
[193] *Loc. cit.*, 397.
[194] Dr. A. Beyer, Die Landw. Vers. Stat., 1871, XIV, 314-322.

vein must be largely due to these erosive agents, does not exceed fifty or sixty feet in depth according to the books, but apparently reaches at least 200 to 300 feet in many of the Western mines, sunken on well-drained fissure-veins; and the ochreous selvage along the walls, and scattered films and bunches along the more continuous and dry fissures, certainly reach to a still greater depth, *e. g.*, 1500 feet in the Eureka mine, in northern Nevada.[195] The material of the gossan has certainly been the seat of a most complex series of chemical reactions, perhaps unsurpassed elsewhere in nature; and in these the acids of humus have played a very important part. This seems to be indicated by the remarkable decomposition and softening of the wall-rock and of refractory sulphides, the deposition of limonite and hyalite, the evidences of strong reduction, as well as intermittent oxidation, the separation of the native metals (copper, silver, gold, etc.) in forms which must have required a strong reducing agent and solvent, the abundance of carbonates and even of combinations of other humus-acids with oxide of iron, etc. The enclosure of brown iron-ore in gold nuggets, the intimate and almost universal intermixture of the brown limonite with minute shot gold, at depths of even 100 feet in mines of North Carolina, as well as the abundant association of gold with the ferruginous conglomerate (Jacotinga) of Brazil, etc., seem to indicate a different agency, perhaps of solution, than that of the inorganic mineral solutions which usually also traverse veins and beds.

Although the deep gossan, heavy *limonitic deposits*, and still deeper decomposition, which are connected with the veins of metallic sulphides, chlorides, tellurides, etc., in the arid and barren plateaus of Nevada, Colorado, Arizona, etc., have been naturally referred to by Dr. Newberry as affected by a "dry rot," I believe that the chemical action and products, there represented, afford indubitable evidence of the existence of abundant moisture and vegetation, and of an extensive humus-layer, during some antecedent period. This seems to be confirmed by the close parallel exhibited upon the South American continent, where the enormous superficial sheets of limonite, shot-ore, and even the ferruginous Tertiary sandstones, of Brazil, now underlying dry plateaus, almost destitute of vegetation, have been certainly derived, according to such observers as L. Agassiz, Hartt, and Dr. R. P. Stevens of

[195] Dr. J. S. Newberry, before N. Y. Acad. Sci., 1880.

summer season, the more complex organic acids can rarely penetrate and in very minute quantities. As they infiltrate downward after a rain, the oozing solution of organic salts of iron, manganese, etc., becomes more and more mixed and saturated with the air which occupies the pores and fissures of the rock; the more complex humus-acids become oxidized to simpler forms; all the silica and the larger portion of the iron, manganese, and other bases, are deposited; most of the ammonia is evolved, locked up in clays, or returned to the surface; and a portion of the iron continues on its downward way as ferrous carbonate, in company with the more soluble carbonates of lime, magnesia, and the alkalies. The limits of this zone, as just explained, are trenched upon or completely included by the upper, through the downward moving floods after the heavy rains of summer and in the course of the rainy season. It is only during the latter that the corrosive action can exert much influence; and during other and ordinary seasons this zone must be chiefly the highway of transport of the products of decomposition of the superficial strata, of their frequent oxidation and deposit, and of their repeated though intermittent re-solution, in the simplest forms, and conveyance to a horizon still more profound.

In the lowest zone of all, the process of corrosion must be exceedingly slow and intermittent, and merging gradually into the metamorphic processes developed by the increasing subterranean temperature. Only the carbonates of the bases are brought down in solution, especially those of the alkalies, and take their important part in the process of metamorphic alteration; while the more complex acids of humus rarely penetrate to so great a depth, and have there merely an ephemeral action and duration.

XV. Action within Veins.

§ 49. *Formation of Gossan.*—The depressions of the surface of the ground, along the course of a vein or elevated bed of soft or erodable ore, have generally invited the gathering of surface waters, the formation of swamps, rich in humus, and the consequent concentration of solutions of its acids. The steep inclinations of the crevices, especially along the planes of contact with the strata traversed, have allowed these solutions to penetrate to enormous depths. The gossan, whose formation as a cap to the

tion, alteration, and transport of mineral substances. This power is least in the ulmates, which can dissolve only carbonates: it is stronger in the humates, which dissolve both carbonates and phosphates: and it is strongest in the crenates, especially that of ammonia, which dissolve carbonates, phosphates, sulphates, simple silicates, and fluorides. The salts thus dissolved remain in solution only in inverse proportion to the degree of their subsequent conversion into carbonates: the latter separating, in crystalline condition, in proportion to their insolubility in carbonated waters. The arsenides of nickel, of cobalt, and of iron, and the sulphides of iron and of lead, reduce salts of the heavy metals in solution in humus-acids, and deposit the metals of the latter in close contact, by a process attended with galvanic action. These observations throw light upon the formation of certain minerals in veins, and the occurrence of pure native metals in close envelopment about the arsenides and sulphides above mentioned.

When the walls of a vein are composed of a very soluble material, like the limestone-strata which enclose the ore-deposits of Illinois, Wisconsin and Missouri, the peculiar erosion of the walls into "chimneys," etc., and the enormous quantity of limonitic ochre which fills up the interstices of the breccia as a cement, seem to indicate the influence of stronger agents besides aerated and carbonated waters. The conversion of chalcopyrite into malachite, azurite, etc., of sphalerite into smithsonite, and of galenite into cerussite and anglesite, imply strong chemical action; and it has been suggested that "smithsonite may even now be forming in the ground to quite a large extent."[201] The known solubility of the lead sulphate and carbonate in solutions of citric and other organic acids adds to the probability of the natural agency of the latter in such veins. The concentration of certain ores, especially limonite, often auriferous, as a solid cap (eisenhut) to a vein just below the gossan, or as a cement to a breccia made up of fragments of the walls, is a further consequence of the superficial chemical changes which have been caused or assisted by organic acids. The contact-deposits, which in Europe are often of great economic importance, also represent such a concentration, *e. g.*, the iron-ores of the Northern Banat.[202] These consist of ferruginous

[201] M. Strong, Geol. of Wis., 1877, II, 691.
[202] Von Cotta, *op. cit.*, 284.

clay, containing nodular masses of limonite and hematite, inserted between mica-schist and curiously eroded limestone, and in part of a limestone-breccia cemented by iron-ore and calcite.

In his discussion of the succession of minerals in lodes, founded on the simple action of carbon dioxide and water, Bischof[203] resorts to the influence of "organic matter" merely for the occasional *reduction* of ferric oxide, and yet confesses his perplexity in regard to the full explanation of the relationship of the modes of solution and transfer of silica and iron-oxide. But the consideration of the humic group of acids, as strong solvents of silica, appears to present the missing clew, both to the solution of silica *from quartz*, as well as from decomposed silicates in the rock, and to its frequent immediate deposition as the first layer of a lode; or, when air was present, to the oxidation of the ferrous oxide, which was after a time abundantly combined and conveyed in the same solvent, and the deposition of ferric oxide as the first layer, and the subsequent precipitation of silica as the second layer, on account of the further oxidation and dissociation of the constituents of the organic solvent.

XVI. Action on Guano deposits.

§ 51. *Presence of humus-acids.*— A conspicuous instance of chemical changes, due to the organic acids, is presented in the sub-aërial accumulations and vein-deposits of phosphatic guano, and in the underlying beds of coral-limestone, especially in regions with heavy rainfall. Baker's, Jarvis, Howland's, and other islands in the Pacific, St. Paul's and Ascension in the South Atlantic, and Monk's, Aves, Navassa, Swan, and Sombrero in the Caribbean Sea, have afforded interesting examples of these phenomena. My observations on the guano-deposit of the last-named island are yet to be published, but the following conclusions are pertinent here. A rich growth of vegetation, and sometimes even of forest, has generally clothed the surface of the loose arenaceous deposit; and even where this growth has since completely disappeared, the mass of the rock-guano is thoroughly permeated by innumerable minute tubular holes, produced by the decay of the rootlets. The decomposition of the abundant organic matter, both vegetable and animal, has yielded a continuous supply of organic acids, in addition to

[203] *Op. cit.*, III, 543.

ammoniacal and alkaline salts, etc. These have effected extensive chemical and physical changes within the deposits, and often upon the material of the underlying stratum which constituted the island. The chief agency of the more complex organic acids, such as humic, crenic, etc., in these interesting changes, is shown by the following facts: that they only of the solvents present can dissolve some of the phosphates (*e. g.*, those of alumina and manganese), which enter largely into the composition of the guano: that the height of the mean annual temperature diminishes largely (by about a third) the content and solvent power of carbon dioxide in atmospheric waters usually obtaining in temperate climates: and that such acids as humic, crenic, etc., have been often distinguished in analyses of these guanos.

§ 52. *General results.*— The following are some of the principal effects which have been produced, mainly by the substances of acid nature dissolved in the meteoric waters: the concretionary aggregation of the amorphous materials, to which the deposits have owed their origin, both in the oolitic grains which constitute the superficial layers and pockets of the guano, and in the large and often huge concretions which are abundantly scattered throughout: the solution of phosphates of lime and their deposit in stalactitic forms in subterranean cavities: the solution and conveyance elsewhere of calcium-carbonate, commonly accompanied by a substitution of calcium-orthophosphate in its place, in fragments of corals, etc., enclosed in the deposit: and in the erosion of fissures in the underlying rock, especially when calcareous, and their contemporaneous occupation by phosphates, especially of calcium, carried down from above.

XVII. Influence upon Minerals.

§ 53. *Common alteration.*— All crystallized minerals in the superficial strata, both in the rock matrix, and lining geodes and veins, exhibit evidences that they have rarely escaped the influence in some degree of the action of organic acids. Often the loss of lustre on surfaces and cleavage planes, the stains and films of iron-ore and manganese-oxide, and even pitted surfaces and cellular material, decayed as by a kind of caries, reveal the action of such solvents. But even when the incipient alteration has not progressed so far, there may be chemical evidences, such as the gases

of empyreumatic odor evolved and the darkening of color produced, on heating a fragment, *e. g.*, in hyalite and in many forms of hydrated ferric oxide. The fetid varieties of calcite, orthoclase, quartz, etc., always of superficial occurrence, seem to indicate the formation of a sulphide and impregnation with organic matter, both perhaps produced by acids derived from the overlying soil.

Several minerals appear to owe their very origin and existence, sometimes exclusively, to the action of the humus-acids. A few examples may be briefly considered.

§ 54. *Limonite.*— The economic importance of this product has caused the observation and record of an abundance of well-known facts. Its concentration in low grounds is commonly attributed to the leaching effect of organic acids upon ferruginous sands, etc., *e. g.*, among the dunes of Denmark,[204] near the rivers of Central Europe and in its northern lakes,[205] etc. The general phenomena have been carefully discussed by Hunt[206] and LeConte, and Dana has recognized the fact that the *main* solvents have been organic acids other than carbon dioxide.[207] Some particulars have been already given in regard to the class of limonite-deposits which have this organic origin, but the full discussion of my observations on this subject is for the present deferred. The large content of iron-ore deposits in organic matters has established this theory of their origin beyond question. The following are among the most significant examples: *humic acid*, in the limnite (bog ore) of Novgorod, Russia,[208] and of New York,[209] in the limonite of Westerwald,[210] and of Braunschweig[211] (12.5–14 per cent.): *apocrenic acid* (2.21 per cent.), *crenic*, and other acids (amounting in all to 15.01 per cent.) in an iron-ochre of St. Anne, Montmorenci, Canada:[212] *crenic acid* in a bog-ore of Smaland,[213] and *ammonium crenate* (4 per cent.), in an oolitic red iron-stone of Belgium:[214] *oxycrenic acid* (1–2.5 per cent.), in a limnite (bog-

[204] Roth, *op. cit.*, I, 597.
[205] Bischof, *op. cit.*, I, 170.
[206] Essays, 13, 22, etc.: also Rep. Geol. Canada, 1863, 511.
[207] Man. of Geol., 1863, 361.
[208] R. Hermann, Erd. Jour. pr. Ch., 1842, XXVII, 53.
[209] Karsten, Karst. Arch., XV, 1.
[210] Ullmann, Ueb., 1814, 314.
[211] Wiegmann, Preischr. Torfes, 1837, 75, 76.
[212] T. S. Hunt, Rep. Geol. Can., 1863, 513.
[213] Gmelin, Handbook Chemistry, XVII, 466.
[214] T. L. Phipson, Compt. rend., 1861, LII, 975.

ore), of Novgorod, Russia,[215] etc. It is stated of the lake-ores of Sweden that they are "always deposited rather toward their banks than in the middle": indicating the almost immediate precipitation of the iron-oxide, on its introduction by drainage-waters from the neighboring hillsides, in the shallow and aerated waters, and in the black vegetable mud, along the shores.

The formation of limonite-ores is so strongly related to organic matters that it has long since been established by Logan, Hunt, etc., that the existence of deposits of iron-oxide of any kind may be taken as highly probable evidence of contemporaneous organic life. It has been further shown[216] that the amount of iron-oxide in recent sediments must be considerably decreased by that locked up in fossil deposits of ore: and, on the other hand, that the conditions for the accumulation of carbonaceous sediments are for the same reason more favorable in the more recent geological periods.

But another class of these ores of common occurrence has resulted from the re-working up and alteration of masses of the various other iron-ores back into their original form of limonite.

H. D. Rogers has made particular study[217] of interesting examples of this kind. A magnetitic slate of his Primal series was observed to be crossed by cleavage-fissures at right angles to the stratification, filled with limonite, which he says has been produced "by the copious admission of the surface waters and atmosphere into the body of the rock." In limonite-beds at various horizons, including the fossiliferous ore of the Surgent series, he attributes the origin of the hydrated ferric oxide to recent concentration in two ways: first, the decomposition of pyrite, the infiltration of waters impregnated with salts of iron, especially the sulphate, and final precipitation, as per-oxide, in contact with calcium-carbonate: secondly, and principally in the Surgent series, in beds of mingled ferruginous and calcareous materials, "the removal by infiltrating water of a part or all of the soluble portion of the ore, chiefly its carbonate of lime, both diffused and in the shape of innumerable organic remains." Many analogies render it probable, that, in both processes, the solvent action of organic acids has been largely concerned.

The conversion of siderite into limonite is a common mode of genesis, in this connection, and one in which the organic acids

[215] Hermann, *idem*.
[216] Hunt, Essays, 229.
[217] Geol. of Pa., 1868, II, Part II, 718 to 733.

may be presumed to act as indispensable solvents, previous to the further oxidation of the ferrous carbonate. Many instances occur in this country in Massachusetts, Pennsylvania, etc., and abroad, in Bavaria, Transylvania, etc.

§ 55. *Pinite.*—There is a class of minerals of secondary and often pseudo-morphous character, *e. g.*, the pinites, which consist of insoluble aluminous residues, resulting from the removal of soluble bases, such as iron, lime, the alkalies, etc., from such minerals as the feldspars, hornblendes, etc. In at least one such case, the killinite of Chesterfield, Mass., as I have recently shown,[218] the solvent of the lithia from the parent spodumene has been an organic medium, probably a mixture of sodium and potassium azo-humates, which has penetrated into the granyte-veins of that region to the depth of at least fifteen or twenty feet, produced this interchange of soluble bases represented by the pinite, and left a notable content of nitrogenous matter in this and its associated minerals.

§ 56. *Sundry minerals.*—Attention has also been called by Dr. Bolton[219] to other minerals, whose incipient alteration or very formation may be referred to the acids of humus.

The green coloration of Amazon-stone from Pike's Peak, Colorado.[220]

The ferrous salt with organic acid diffused through cryptocallite (Dr. G. E. Moore).

The organic substance, containing nitrogen and carbon, which produces the color of smoky quartz.[221]

Whewellite, calcium oxalate ($2\ Ca\ O + 2\ C^2\ O^3 + 2$ aq.), occurring in small crystals on calcite (Brooke).

Thierschite,[222] another calcium-oxalate, forming a "grayish warty, and somewhat opaline incrustation" on the columns of the Parthenon at Athens. Its origin is attributed to the action of lichens on the marble.

Humboldtine ($2\ Fe\ O + 2\ C^2\ O^3 + 3$ aq.,) hydrous ferrous oxalate, forming an incrustation upon brown coal in Europe, and, in this country, upon bituminous pyritiferous schists, on Lake Huron. In the latter case, however, the oxalic acid may owe its origin to

[218] Ann. N. Y. Acad. Sci., 1879. I, 340.
[219] Ann. N. Y. Acad. Sci., 1877, I. 34.
[220] G. A. Koenig, Proc. Acad. Nat. Sci., Phila., 1876, 155.
[221] A. Forster, Pogg. Ann., 1871. CXLIII. 173. 193.
[222] Liebig, Ann. Chem. Phar., 1853. LXXXVI, 113.

ore), of Novgorod, Russia,[215] etc. It is stated of the lake-ores of Sweden that they are "always deposited rather toward their banks than in the middle": indicating the almost immediate precipitation of the iron-oxide, on its introduction by drainage-waters from the neighboring hillsides, in the shallow and aerated waters, and in the black vegetable mud, along the shores.

The formation of limonite-ores is so strongly related to organic matters that it has long since been established by Logan, Hunt, etc., that the existence of deposits of iron-oxide of any kind may be taken as highly probable evidence of contemporaneous organic life. It has been further shown[216] that the amount of iron-oxide in recent sediments must be considerably decreased by that locked up in fossil deposits of ore: and, on the other hand, that the conditions for the accumulation of carbonaceous sediments are for the same reason more favorable in the more recent geological periods.

But another class of these ores of common occurrence has resulted from the re-working up and alteration of masses of the various other iron-ores back into their original form of limonite.

H. D. Rogers has made particular study[217] of interesting examples of this kind. A magnetitic slate of his Primal series was observed to be crossed by cleavage-fissures at right angles to the stratification, filled with limonite, which he says has been produced "by the copious admission of the surface waters and atmosphere into the body of the rock." In limonite-beds at various horizons, including the fossiliferous ore of the Surgent series, he attributes the origin of the hydrated ferric oxide to recent concentration in two ways: first, the decomposition of pyrite, the infiltration of waters impregnated with salts of iron, especially the sulphate, and final precipitation, as per-oxide, in contact with calcium-carbonate: secondly, and principally in the Surgent series, in beds of mingled ferruginous and calcareous materials, "the removal by infiltrating water of a part or all of the soluble portion of the ore, chiefly its carbonate of lime, both diffused and in the shape of innumerable organic remains." Many analogies render it probable, that, in both processes, the solvent action of organic acids has been largely concerned.

The conversion of siderite into limonite is a common mode of genesis, in this connection, and one in which the organic acids

[215] Hermann, *idem*.
[216] Hunt, Essays, 229.
[217] Geol. of Pa., 1868, II, Part II, 718 to 733.

may be presumed to act as indispensable solvents, previous to the further oxidation of the ferrous carbonate. Many instances occur in this country in Massachusetts, Pennsylvania, etc., and abroad, in Bavaria, Transylvania, etc.

§ 55. *Pinite.*—There is a class of minerals of secondary and often pseudo-morphous character, *e. g.*, the pinites, which consist of insoluble aluminous residues, resulting from the removal of soluble bases, such as iron, lime, the alkalies, etc., from such minerals as the feldspars, hornblendes, etc. In at least one such case, the killinite of Chesterfield, Mass., as I have recently shown,[218] the solvent of the lithia from the parent spodumene has been an organic medium, probably a mixture of sodium and potassium azo-humates, which has penetrated into the granyte-veins of that region to the depth of at least fifteen or twenty feet, produced this interchange of soluble bases represented by the pinite, and left a notable content of nitrogenous matter in this and its associated minerals.

§ 56. *Sundry minerals.*—Attention has also been called by Dr. Bolton[219] to other minerals, whose incipient alteration or very formation may be referred to the acids of humus.

The green coloration of Amazon-stone from Pike's Peak, Colorado.[220]

The ferrous salt with organic acid diffused through cryptocallite (Dr. G. E. Moore).

The organic substance, containing nitrogen and carbon, which produces the color of smoky quartz.[221]

Whewellite, calcium oxalate ($2\ Ca\ O + 2\ C^2\ O^3 + 2$ aq.), occurring in small crystals on calcite (Brooke).

Thierschite,[222] another calcium-oxalate, forming a "grayish warty, and somewhat opaline incrustation" on the columns of the Parthenon at Athens. Its origin is attributed to the action of lichens on the marble.

Humboldtine ($2\ Fe\ O + 2\ C^2\ O^3 + 3$ aq.,) hydrous ferrous oxalate, forming an incrustation upon brown coal in Europe, and, in this country, upon bituminous pyritiferous schists, on Lake Huron. In the latter case, however, the oxalic acid may owe its origin to

[218] Ann. N. Y. Acad. Sci., 1879, I, 340.
[219] Ann. N. Y. Acad. Sci., 1877, I, 34.
[220] G. A. Koenig, Proc. Acad. Nat. Sci., Phila., 1876, 155.
[221] A. Forster, Pogg. Ann., 1871, CXLIII, 173, 193.
[222] Liebig, Ann. Chem. Phar., 1853, LXXXVI, 113.

In addition to the three foregoing modes of genesis, hitherto accepted, I have now to suggest:

4. *Deposit from solution in organic acids*, especially the silico-azo-humic, derived from overlying humus and infiltrating through subterranean fissures. The hyaline silica, due to this source, has assumed two forms: the one, *hydrated*, hyalite, as a kind of vein-deposit, in crusts upon the walls of fissures: and the other, but in small part hydrated, as amorphous masses of flint, chert, etc. — within the body of limestone-strata.

§ 58. *Hyalite crusts.*—The prevailing opinion in regard to the distribution of a mineral in nature is apt to be influenced by the abundance of those of its varieties which are prized and searched after by miners, mineralogical collectors, etc. It is certain that hyalite, far from being rare, is a form of silica of exceedingly common occurrence, though almost always in small and inconspicuous quantity. A few instances of recent observation may be mentioned. From beneath the great overflow of diabasyte along the Hudson river, called the "Palisades," the underlying Triassic beds project at many points, in an altered condition, and have been styled "trappean schists." At Weehawken, N. J., I found the surface of the joints in this rock to be covered with hyalite in considerable abundance, in the form of thin crusts and rosettes. Color, shades of brownish-white to colorless. Sp. gr., 2.041, in coarse powder and distilled water at 67.5° F. Like hydrophane, it evolved minute bubbles of air in large numbers, on immersion in warm distilled water, and it required a continued immersion of 48 hours to expel them completely. On ignition, it lost 9.37 per cent. of water and organic matter, evolving empyreumatic and ammoniacal odors.

The conditions of its origin are simple. The surface of the talus of fallen fragments, at the base of the dyke, is overspread, sometimes quite thickly, with a layer of rich black humus, which is kept moist by streams trickling down from and through the vertical face of columnar trap. It is covered by a dense forest with thick shrubbery, and in many places supports a luxuriant growth of ferns, mosses, etc. The organic acids, developed in this rich forest-soil, are carried down among the fallen fragments of trap; and, partly by the decomposition of that rock, especially of its viridite and of the films of chlorite which coat the fissures, and, it may be, partly by that of the schists — in which analyses have

shown a cement of opal-silica — the solution becomes saturated with silica, and redeposits it, by evaporation, as hyaline crusts upon the walls of the joints below. The trace of organic matter, which imparts the color of the mineral and its odor on ignition, evidently represents a portion of the organic solvent matter included in the gelatinous deposit during its desiccation. Similar thin crusts upon the surface of the trap, possessing a snow-white color and beautiful pearly lustre, have been obtained in the vicinity by Prof. D. S. Martin of New York, and it is probable that the mineral abounds along the whole dyke.

Again in many of the mica-mines of North Carolina, similar occurrences of hyalite have been observed by Dr. H. C. Bolton and myself. At Juggenheim's mine, on the North Toe river, in Yancey county, the walls of the joints of the granyte-veins were often covered with hyalite, in thin crusts of delicate yellowish-green color (caused by a small proportion of ferrous silicate), sometimes associated with and even overlying films of uranochre. A spectroscopic examination disproved the supposition that the green tinge was produced by uranium-oxide. Sp. gr., 2.00. Minute bubbles of air were expelled in great numbers on immersion in water, with increase of transparency. Loss by ignition, 8.35 per cent. It decrepitated slightly in a matrass, and yielded an empyreumatic odor and vapors that turn red litmus paper blue, *i. e.*, are ammoniacal. At the Puzzle mine, in Mitchell county, a hyalite of greenish-blue color occurred in similar crusts. At both localities, the surface of the ground, above the quarry, was clothed with an almost virgin forest and heavy undergrowth of rhododendrons, springing from a thick layer of rich black humus.

The analyses of opal and hyalite from various foreign localities frequently indicate the presence of nitrogenous organic matter and of ammonia.[228] Even the true opal of Mexico and Hungary evolves such decided empyreumatic and ammoniacal odors, on ignition, that Damour[229] ventured to ascribe the peculiar reflections of the gem to the presence of carbonaceous matters.

§ 59. *Formation of chert, flint, etc.*—We have next to consider the influence of organic acids in the concentration of hyaline or amorphous silica within the mass of strata. Bischof,[230] Hunt,[231]

[228] Rammelsberg. Min. Chem., 1875, II. 164. See also Fournet, on "Organico-mineral colouring principles." Compt. rend., 1860, l. 1175: 1860, li. 39, 140.

[229] Ann. Min., 1840, (3), XVII, 207. [230] *Op. cit.*, II, 465, etc. [231] Essays, 89.

and others have treated of the separation of this substance from its solution in sedimentary deposits, as crystallized or chalcedonic sands, in the silicification of fossils, in beds of flint, etc. LeConte has recently suggested[232] that the silicification of wood, and perhaps the cementation of gravel, have been effected in California and elsewhere by the precipitation of silica in an insoluble form, through the neutralization of percolating alkaline solutions, charged with silica, by the humic, ulmic, and other acids of organic décomposition; the same process may very probably account for the siliceous cement in the interstices of many ancient sandstones, etc., especially if formerly rich in organic remains. The frequent and extensive silicification of wood in Tertiary deposits may have been, in many cases, therefore, connected with solutions of humus-acids during its decay, as well as with its recognized subsequent solution and re-deposition by thermal waters. Silicified trunks have been often observed in Colorado,[233] in which the material is found to be carbonaceous internally and at the heart passes into charcoal.

Many cherty layers probably owe their origin to the metamorphism of ancient infusorial deposits, and even their partial transport, by organic solvents, with an alteration often so complete as to nearly or completely obliterate the minute organic forms. Ehrenberg thus found[234] that the infusorial beds, near Kolt and Geistingen, do not contain any empty shells, but are all filled with siliceous substance; the tripoli and rottenstone, largely used in the arts, consist in great part of the frustules of Naviculæ and Pinnulariæ; and the polishing-slate of Bilin in Bohemia, and especially the well-known Turkey-stone, "seem to be essentially composed of a similar aggregation of frustules of Naviculæ, etc., which has been consolidated by heat."[235]

However, the origin of the chert and flint-layers which so strongly characterize the Carboniferous and Cretaceous strata, as well as many of Palæozoic age,[236] seems now to be better explained in the light of the revelations from the deep-sea ooze, already discussed, and of the approximate identification of the long-sought-for solvents of silica. The almost identical conditions

[232] Am. J. Sci., 1880, (3), XIX, 181, footnote; El. of Geol., 193.
[233] Letter from Capt. E. H. Ruffner, Fort Leavenworth, Kansas.
[234] Sitz. d. Berl. Ak. d. Wiss., 1846, May.
[235] Carpenter, The Microscope, 1875, 336.
[236] Dana, *op. cit.*, 377.

and materials which have been proved to exist, in the present as in the ancient Cretaceous seas, have acquainted us with all the steps in the process, depending upon time: from the recent mixed sediments, which contain up to 54.9 per cent. of silica, to its isolation in the flint-layers, out of a rock, the Chalk, the mass of whose material still retains very rarely as much as 3 or 4 per cent.[237] of silica, usually about half of one per cent.,[238] and this, apparently, no longer remaining in organized form.[239] The process has been well described in the following passage:

"In the chalk, which contains not a trace of silica, we often find the moulds and outlines of organisms which we know to have been siliceous, from which the whole of the silica has been removed; and I have more than once seen cases in which a portion of the delicate tracery of a siliceous sponge has been preserved entire in a flint, while the remainder of the vase which projected beyond the outline of the flint appeared in the chalk as a trellis-work of spaces, vacant, or loosely filled with peroxide or carbonate of iron. It therefore seems certain that *by some means or other* the organic silica, distributed in the shape of sponge-spicules and other siliceous organisms in the chalk, has been dissolved or reduced to a colloid state, and accumulated in moulds formed by the shells or outer walls of embedded animals of various classes. *How the solution of the silica is effected we do not know precisely.* Once reduced to a colloid condition, it is easy enough to imagine that it may be sifted from the water by a process of endosmose, the chalk-matrix acting as a porous medium, and accumulated in any convenient cavities."[240]

The means and mode of solution of silica, concerning which this author expresses doubt, in the passages I have italicized, can be now with some probability referred to albuminoid or glairy matters, and acids akin to the azo-humic of Thenard, produced during submarine decomposition of the organic matter infiltrating into and disseminated through the sediments. To this solvent agency may be also attributed the concentration of perhaps nearly all deposits of amorphous silica as chert, hornstone, etc., in other calcareous beds. It may also be suspected that the same organic

[237] By analyses of D. Forbes, 1.10 per cent. in white chalk of Shoreham, and 3.61 per cent. in the grey chalk of Folkestone, Eng. (Depths of the sea, 514).

[238] F. T. Hardmann, Geol. Mag., 1878, X, 434.

[239] F. Kitton, Hardw. Sci. Gossip., 1878, XIV, 277.

[240] Thomson, Depths of the Sea, 481.

agency may have been concerned in the formation of the Gaize of the Ardennes, a siliceous layer underlying the Cretaceous strata and sometimes 100 meters in thickness, containing from 29 to 47 per cent. of soluble silica.[241] If its origin, like that of the flint, has been submarine and contemporaneous with the deposition of the overlying sediments, we may conjecture the possible existence of a similar layer at a certain depth below the ooze of the present deep-sea deposits.

§ 60. *Other theories.*—Renard, however, in his recent excellent paper[242] on the *pthanites* (schistose chert-layers), in the Carboniferous limestone of Belgium, though he recognizes the important fact that "the silicification has taken place before the formation of the joints and fissures," offers the provisional theory that when "at certain intervals the waters of the Carboniferous sea holding in solution a solvent of the limestone, carbonic acid for example, attacked the calcareous matters, silicic acid was infiltrated into the calcareous sediments and impregnated them in proportion as they were decomposed." He further holds that the details of the micro-structure of the chert "prove also that it is impossible to admit, in order to explain the formation of the pthanites, as has been so often repeated in regard to flint, that these rocks are derived from the accumulation of organisms with siliceous envelopes." This he considers proved, both by the very exceptional enclosure of such organisms, for example in flint,[243] and by the difficulty of accounting, by that theory, for the perfection of their preservation. He therefore concludes: "finally we add that our pthanites present no analogy with the deposits of microscopic siliceous organisms pointed out by Ehrenberg, especially in Bohemia and in Sicily, nor with the siliceous sediments which the exploration of the deep seas has shown in progress of formation upon the bed of the ocean."

A somewhat analogous view has been also advanced in regard to the chert-beds in the Upper Carboniferous limestones of Ireland:[244] that at the close of the period of the latter, "the sea-bed was elevated, so as to be covered by the waters of a shallow sea, exposed to the sun's rays, and of a warmer temperature than

[241] Compt. rend., 1870, LXX, 581, and 1871, LXXII, 767.
[242] Bull. de l'Ac. roy. de Belg., 1878, (2), XLVI, Nos. 9 and 10.
[243] J. Wright, Rep. Brit. Assoc., 1874, 95.
[244] E. Hull and E. T. Hardmann, Proc. Roy. Soc., 1878, XXVI, 163.

when at a greater depth:" that the waters became charged with an unusual supply of silica, derived from the siliceous rocks of the surrounding lands: and that a chemical replacement of silica for calcium-carbonate took place, the access of the sea-waters being facilitated by their warmth, by the porous character of the limestone, the softness of the ooze, etc.

But the conditions required by the latter theory must then have been very common, attending the formation of chert-beds of all ages; and yet no such saturation of sea-waters by silica is now known to occur. Such a deposit of silica would have developed transverse veins or aggregations of a crystalline material; and it could hardly have produced the isolated nodules and layers, amorphous material, and concretionary structure, presented in chert and flint.

In reply to Renard's argument, it may be remarked that purely calcareous beds, undoubtedly made up entirely of organic material, often present similar modes, both of obliteration and of the occasional protection and perfect preservation of certain individual organisms; and I have found, after the microscopical examination of very many thin sections of flint from France and England, that specimens are exceedingly rare in which no traces of organic forms may be detected, while those are very common in which the material is thronged by such forms, in various degrees of perfection. We may also expect in time to determine the conditions which have differentiated the deposition of colloid silica in the Cretaceous beds as flint, and in other limestones as hornstone, chert, chalcedony, jasper, agate, etc. Numerous examinations of these last amorphous or crypto-crystalline forms of silica, in thin sections, by polarized light, show a more distinct granulation than that of flint, often fibro-radial, and with much stronger refractive energy. This indicates, in the condition of genesis — or at least of the last metamorphism, a solvent and crystalline exertion which must naturally have accomplished the general obliteration of most of the more minute organic forms. Flint, hornstone, and amorphous chert, therefore seem to me to present *the colloid form of silica necessarily deposited from a solvent of a colloid nature*, such as humic[245] and probably the azo-humic acids have been found to possess. Granular chert, jasper, etc., on the other hand, appear to be the crystalline forms of silica,

[245] Detmer, *vide ante*.

probably in part deposited from solution in thermal waters, in the course of the metamorphism which has generally affected the pre-Cretaceous sediments in which they occur.

The universal presence of siliceous particles, in all the calcareous sediments now being deposited, seems fairly to justify the presumption of their presence in the ancient sediments. The conditions of decomposition within the sediments naturally differing in various parts, according to the character of the material, entrance of aerated waters, temperature, etc., the results of decomposition have also varied. In certain parts, the organic acids were probably largely developed for the solution of all adjacent silica, while elsewhere the organic matter was perhaps mainly destroyed and its place subsequently occupied in part by infiltration from the silica-solution.

Petzholdt has found[246] in the Silurian dolomitic beds of Lievland, that, where the average content of silica in the rock was 4.7 per cent., this content decreased to 2.3 per cent. in the close vicinity of the hornstone nodules. Bischof reasonably concludes from this[247] that the silica of the nodules has been derived simply from concentration of that in the surrounding rock; and his only question, which he does not attempt to answer, relates to the nature of the solvent, — in these beds as in chalk, the action of carbon dioxide being evidently not pertinent, nor the intervention, suggested by Dana, of the alkaline waters of the ocean.[248]

There seems no need to go outside of such sediments for the source of silica: all analogy renders it probable that its indigenous amount was sufficient. Ehrenberg and Murray, it is true, have recorded the silicification of foraminifera in the deep-sea ooze, the thin layer in direct contact with the sea-water; but the abundant supply both of silica and of decomposed organic matter, as its solvent, throughout the enveloping ooze, affords a satisfactory explanation of this phase of the process. Indeed, it is difficult to see how there could have been — as the theories of both Renard and Hardmann, above-quoted, require — especially before the formation of fissures and joints, the passage and diffusion of so great a volume of the sea-water, containing only 0.002 per cent. of silica,[249] through vast masses of the finest sediments, mostly consolidated and under enormous pressure, to furnish the enormous

[246] Silicification organischer Körper, 1853, 20. [247] *Op. cit.*, II, 490.
[248] Man. of Geol., 488. [249] Roth, *op. cit.*, I, 505.

quantity of silica concentrated in the nodules of chert or flint. The negative considerations of Renard do not therefore seem to me to bear much weight against the overwhelming analogies which have been noted in the ancient and recent examples of the submarine aggregation of amorphous silica.

XIX. Periods of Special Activity.

Certain periods in geological time seem to have been especially characterized by the activity of the chemical reactions under discussion, as recently presented in some detail by Le Conte.[250]

§ 61. *Archæan.*— Hunt attributes the alternation of white feldspathic beds, poor in iron, with beds of iron-ore, to the intervention of organic matters, *e. g.*, in the Green Mountain rocks of Canada, and particularly in those of the Laurentian series, with their additional association of graphite. The exhaustion of iron-oxide from the Laurentian rocks, also pointed out, is indicated by their remarkable poverty in the oxide in a diffused form, which appears to have been concentrated in the heavy and numerous beds of ore. On these grounds, it has been claimed that "we may probably look upon the formation of beds of iron-ore as in all cases due to the intervention of organic matters; so that its presence, not less than that of graphite, affords evidence of the existence of organic life at the time of the deposition of these old crystalline rocks."[251]

The abundance of iron-oxide deposited in the Huronian sediments is illustrated by the fact, that, notwithstanding its common concentration in vast ore-deposits, the interbedded rocks remain highly basic and ferruginous.

There are indications in the Cambrian beds, which have induced the palæontologist to believe that "the earliest life of the globe must have been vegetable,"[252] and I think that the chemical results further prove the existence at that time of abundant land-vegetation. This may possibly have been cryptogamic, when we consider the established existence of algæ in the ocean-waters of that age, the ready transport of their spores, and their susceptibility to modification. The facts certainly indicate an amount of chemical action, revealed in the solution, transport, and deposit of iron-oxide, which was enormous, if not in intensity, at least in its accumulation by

[250] El. of Geol., 374. [251] Hunt, *op. cit.*, 13, 30. [252] Jukes, Man. of Geol., 439, 445.

time, and probably unequalled by the entire amount of similar action through all subsequent ages. And, although the conditions were not such as to render it the greatest of the Carboniferous ages, by the storing up of the element indicated by that name, the fact that the Archæan was of all others the Ferriferous age points as definitely to the vast antiquity of vegetable life, in the form of land-vegetation, and to the solvent action of the results of its decay — the humus-acids. The products of this action appear to have been three in number, — the iron-ores (chiefly magnetites), the aluminous strata, and a vast mass of siliceous sands — which afforded the materials worked over and over again,[253] by all agencies, throughout at least all Cambrian and Silurian time, to provide the hematites and limonites, the aluminous schists, and the siliceous quartzytes and sandstones of the earlier Palæozoic epochs.

§ 62. *Palæozoic.*— Throughout Palæozoic time the abundant occurrence of beds of iron-ore, in numerous localities, indicates the presence and chemical influence of the same organic agencies. Such ores, for instance, abound particularly, according to H. D. Rogers, in Pennsylvania, in the Primal, Auroral and Matinal, and Surgent series: and in Virginia, according to T. Egleston, in the Potsdam, Trenton, Clinton, Oriskany, and Hamilton shales. Rogers attributes these ores to the oxide derived from upraised Primal, or later sediments, washed down into the ocean along with calcium-carbonate.

The abundant deposits of limonite of the Great or Cumberland Valley, belonging to the Calciferous epoch, have attracted much investigation, resulting in diverse views concerning their origin. It has been explained[254] that they always rest upon impervious damourite-slates, which stopped the flow of ferruginous waters and occasioned the accumulation of these deposits. Whatever the source of the iron-oxide may have been, whether pyrite or other ferruginous minerals in the limestones, dolomytes, or other associated rocks, the action of humus-acids may be suspected in connection with this ore, *limonite*, their ordinary product. They have probably served for its transport, and as the erosive agents in the excavation of the numerous limestone-caverns (instead of that which has been suggested, the dissolving action of water containing ferrous sulphate). If it shall be possibly established that

[253] Dana, *op. cit.*, 209. [254] F. Prime, Jr., Am. J. Sci., 1875, (3), IX, 433.

the iron was first deposited as carbonate, its solution and decomposition were probably accomplished by these acids, previous to its oxidation and hydration.

In the Medina period of the American continent the coast region consisted of "low sandy seashores, flats, and marshes;" and in the Clinton period the widely spread beds of argillaceous iron-ore are proof, both of extensive marshes, and, although no plant-remains are known, of a land-vegetation and its decay, by which only the concentration of iron-oxide could have been effected.

During the Devonian, the beds of the Oriskany period in Nova Scotia also contain argillaceous iron-ores, now sometimes magnetic, which testify to a land-vegetation and humus-layer, notwithstanding the present absence of the remains of land-plants.

§ 63. *Carboniferous cherts and iron-stones.*— The decomposition of enormous quantities of vegetable matter, during the Carboniferous age, was accompanied by a vast development of the humus-acids, by a corresponding amount of chemical sub-aërial erosion in the superficial strata above the water-level, and by the deposit of large quantities both of ferric oxide *and of colloid silica.* It is a significant fact that the iron-ores of the coal-measures are *intimately associated with a chert or buhrstone*, and the ores of ferrous carbonate themselves contain, as collated from over fifty analyses given by Rogers, from about 6 to 60 per cent. of silica,[255] the more siliceous being termed "buhrstone-ore." The transport both of the iron-oxide and of this large quantity of colloid silica, represented by the chert, necessarily involves the agency of silico-azo-humic acids, in addition to the carbon dioxide considered by Rogers.

In the Carboniferous measures of England, the "seat-stone" of the coal-beds sometimes consists of a "very hard flinty rock," known as *ganister* in Yorkshire. In Upper Silesia and Poland "beds of clay iron-stone (spherosiderite) are tolerably common. They occur principally in those localities where numerous and thin coal-seams alternate with argillaceous shales. This clay iron-stone appears to be confined to the upper strata of the Carboniferous and near thin coal-seams. It is entirely wanting where thick coal-beds occur. It is to be accepted as a practical rule, that these iron-stones generally occur in the foot-wall of thin seams, and in

[255] Geol. of Pa., 1868, II, Pt. II, 739.

the hanging wall of broad coal-beds. Still this rule has many exceptions."[256] The ores consist partly of argillaceous spherosiderite and partly of argillaceous limonite — the latter possibly formed by alteration of the former.

In considering the origin of the associated deposits of clay iron-stone, Bischof has pointed out[257] that "the formation of coal, proto-carbonate of iron, and other carbonates, may have gone on simultaneously" in argillaceous strata associated with the coal, on account of the excess of organic matter present: "but at the same time it must be understood that such a formation of carbonates could also have taken place after the coal formation was raised above the sea" by the reducing influence of the gases, gradually evolved during the subterranean decomposition and transformation of vegetable deposits into coal, penetrating original deposits of ferric oxide in clay-beds overhead.[258] Rogers accepts the latter theory for the formation of the iron-stone deposits in the coal-measures of Pennsylvania.[259] Recently, however, in his general and excellent discussion of the work of the humus-acids in the transport and concentration of iron-oxides, LeConte[260] rather dwells upon the initial deposit of ferrous carbonate as probable, merely under the condition of "the presence of excess of organic matter," both in recent peat-bogs and in those of the Carboniferous period. But it is an important fact, that, so greedy are solutions of ferrous salts for oxygen,[261] that recent instances of the permanent deposit of ferrous carbonate are *extremely rare*,[262] occurring only at chalybeate springs, never in bogs, and are always accompanied by conditions of perfect protection from the air, *e. g.*, by thick layers of clay or of ferric oxide derived from the oxidation of the carbonate itself. Again the known deposits of any form of iron-ores by bog-waters, now in progress, rarely occur in immediate contact with the beds of organic matter, but in separate basins, as in the Swedish lakes, or near the *outlets* of swamps and peat-bogs, where the aeration of the slowly flowing and highly dilute solutions causes the precipitation. The view

[256] Von Cotta, Treatise on Ore Deposits, 244.

[257] *Op. cit.*, I, 315.

[258] *Idem*, 170–1; also German Suppl., 1871, 64–70.

[259] Geol. of Pa., 1868, II, Pt. II, 736–739. See also Von Cotta on a similar reaction in ores of the lower Cretaceous, Ore Deposits, 257.

[260] El. of Geol., 1879, 136–7, 374–5.

[261] Bischof, *op. cit.*, I, 155. Fresenius, J. pr. Chem., 1855, 64, 368.

[262] Bischof, *op. cit.*, I, 156–7.

adopted by Rogers seems to me therefore at present the more probable, since iron-stone deposits are never found in direct contact with coal.

In explanation of the general association of the iron-ore with thin layers of coal, it need only be stated, that the heaviest beds of coal imply the longer subsidence, deeper waters, enormous excess of organic acids, and absence of basins, comparatively free from the reducing and therefore solvent action of humus, for the reception of the precipitate of ferric oxide. On the other hand, numerous alternations of shale with thin layers of coal indicate also occasional shallow basins of more thoroughly aerated water, in which the iron-deposit could be thrown down: and that too in abundance, in the absence of thick beds of coal, as in the Upper Carboniferous measures of Silesia and Poland. Again the re-conversion of carbonate into hydrated ferric oxide reveals that the iron, which owed its first removal, transport, and concentration, to the solvent action of the humus-acids, was at a later period, after its transformation into ferrous carbonate, again subjected to their action in intermittent solution and oxidation.

§ 64. *Coloring material of sandstones.*—In England, the prevailing colors of the Upper Coal-measures are red, purple, and mottled red and green. "The rocks of which the group is made up are mainly shales and sandstones; it contains seams of coal, but they are neither so numerous nor so thick as those of the Middle Coal-measures."[369] In these red rocks each grain is enveloped by a thin skin of ferric oxide, implying its concentration in the waters in which these sands were deposited. Prof. Green hence concludes that the water was itself red as blood, on account of the suspended iron-oxide; that its retention was due to the closing up of the outlets of the lakes in which the sandstones and shales were formed; that the associated limestones, sometimes [illegible] and occasionally possessing a porous spongy [illegible] were precipitated in such circumstances from [illegible] and that the source of the [illegible] was [illegible] by the [illegible]

[illegible]

the ferric oxide. The westward prolongation of the Archæan rocks of the Scandinavian peninsula, referred to by this author, probably covered by heavy vegetation and swamps, must have afforded an ample area and volume of ferruginous materials for the solvent action of humus-acids on a vast scale and through a long period, sufficient to have supplied the ochreous cement of the sandstones in the Carboniferous seas.

The principal investigation, of which I am aware, on the subject of the coloring material of such ferruginous sandstones, one so important in its relations to the modern accumulations of bog iron-ores, was made thirty years ago by Dawson, in reference to the red sandstones, and associated greyish and white beds, of the Lower Carboniferous formation in Nova Scotia, in which he comes to the following conclusions.[264] He recognizes that "the red coloring matter, which is the peroxide of iron, is in a very fine state of division, having indeed rather the aspect of a chemical precipitate than of a substance triturated mechanically." The source of the detrital matter of the sandstones, he finds in the Silurian, metamorphic and hypogene rocks, which have formed the ridges between the basins of deposit during the Carboniferous period: and that of the ferric oxide, in the pyrite disseminated through the immense masses of these older formations. During the alteration of the latter by igneous agents, he suggests that the pyrite in the superficial deposits has been converted into peroxide of iron and sulphuric acid, or sulphuretted hydrogen subsequently oxidized to sulphuric acid; and while the detritus was mainly colored through this agency by the iron-oxide, the acid was carried into the sea and combined with calcareous matter in the form of the present beds of gypsum. The decoloration, shown in the grey, dark, and white beds, he attributes to two possible causes, both acting contemporaneously with the process of deposition. First, in marine deposits, to the deoxidizing influence of decaying vegetable matter and the conversion of oxide of iron into sulphide, in the presence of the sulphates of sea-water. Of this he gives an interesting illustration from the decoloration of the reddish mud deposited by the streams upon the mud-flats, covered by eel-grass, in the harbor of Pictou, N. S. Secondly, in fresh water deposits, to "the action of acids produced in the

[264] Quart. Journal of Geol. Soc., 1849, V, 25.

putrefaction and decay of moist vegetable matter," making reference to the phenomena presented in peat-bogs and swamps.

To the main theory I think it may be fairly objected that the concentration, especially to such a degree, of an unstable mineral like pyrite, among superficial detrital deposits, as well as its distillation in the manner suggested, is unprecedented and improbable. Again, the amount of pyrite disseminated through the ancient formations (if we take, like Dawson, the standard of its proportion in present unaltered remnants) is *by no means* sufficient to have supplied the immense quantity of ferric oxide in the later sediments. The same objection may be made to *magnetite*—to which Dana attributes the derivation of the iron-oxide in the Triassic sediments, apparently from the agencies attending the eruption of the trap-dykes (Manual of Geology, 1863, 432)—on the ground both of the insufficient amount of that mineral, and its refractory nature toward any agencies likely to have attacked it during the short duration of submarine volcanic eruptions. On the other hand, the ferruginous minerals, hornblende, chlorite, orthoclase, and the iron-garnets, not mentioned by Dawson, are characteristically prominent and abundant in the parent crystalline rocks of Archæan age, and even occur in the sediments, and are readily assailable by agents of decomposition. *Biotite* also abounds in Archæan rocks. Bischof calls attention[265] to its remarkable absence from most sandstones, notwithstanding their richness in muscovite, and attributes this to its more ready decomposition. J. W. Young detected the mineral only twice, in his examination of the Carboniferous sandstones of England,[266] but R. Lincke seems to have found it more commonly in the Triassic sandstones of the Thuringian basin.[267] The full explanation may be found in the observation of P. Schweitzer, in 1871, on the superficial decomposition of the gneiss of New York island, that "the black mica, after getting first coated with a brown film of oxide of iron, becomes rapidly disintegrated and disappears. The white mica possesses a much greater resistance, and abounds, therefore, in places from which feldspar and black mica have completely disappeared."[268] Little biotite has therefore passed into the sediments which compose sandstones, and even there has

[265] Chem. and Phys. Geol., III, 113.
[266] Chem. News, 1868, III, 307.
[267] Jahresb. f. Min., 1871, I, 15.
[268] Am. Chem., 1874, IV, 444.

been often subjected, as the thin sections of the sandstones show, to the later attack of meteoric and organic agents of decomposition. In the alteration of this mineral we may therefore find an important source of the iron-oxide in the Carboniferous and most ferruginous sandstones.

§ 65. *Mesozoic.*—Throughout this age, especially during the Triassic and Cretaceous periods, the coal-measures and occasional beds of argillaceous iron-ore both testify to the same activity of the humus-acids.

In the Triassic beds an abundance of plant-remains occurs, and even beds of coal of considerable extent in India and New South Wales, and, associated with argillaceous iron-ore, in Virginia and North Carolina.[269] In the Jurassic, the numerous remains, not only of plants, but of insects, of insectivorous and herbivorous mammals, and of reptiles, "prove that the land was covered with foliage and swarming with life,"[270] and even beds of coal and iron-stone occur in the Oolite of England.[271] In the Cretaceous, beds of lignite abound, and even beds of good coal in the central part of British North America.[272]

It may be added that in the beds both of this and other ages, the evidences of numerous oscillations of level, shallow water, emerging flats, and dry land intervals—the abundant distribution of lignite-layers—and even the highly ferruginous sandstones and shales, testify sufficiently to the distribution of a sub-aërial humus-layer, and to the extensive erosion carried on by its organic acids.

§ 66. *Cenozoic.*—The increased extent of the dry land during the Tertiary period was attended, as is well known, by a mild and genial climate, and by a great development of terrestrial vegetation, both as to variety and luxuriance. This is now shown by the abundant leaf, lignite, and forest-beds, and even coal, iron stone, red-ochre, and the vast bodies of ferruginous sands and clays.

Again, after its interruption in the higher latitudes by the barren desolation of the Glacial epoch, perhaps with occasional return, during the warmer interglacial intervals so fully discussed by Croll and Geikie, there is every indication that the withdrawal of the ice-layer was ultimately followed by a heavy forest-growth, and, subsequently over certain areas, by the extension of bogs and marshes and the filling up of innumerable lake-basins by

[269] Dana, *op. cit.*, 418. [270] Dana, *idem*, 466.
[271] Jukes, *op. cit.*, 565, 576. [272] Dr. Hector, Quart. Jour. Geol. Soc., XVII.

peat.[273] The growth and decomposition of vegetable matter may have been further increased, as suggested by C. H. Hitchcock,[274] by the intercalation of warmer post-glacial periods. The accumulation and continuous decomposition of vegetable matters during this long period afforded the conditions for a remarkable amount of chemical alteration. This is represented by the deep disintegration of the rocks over all surfaces not swept by the ice-layer, as well as the wide distribution of bog-ores, infusorial earths, cherts, and other chemical deposits already sufficiently considered.

§ 67. *General review of the sandstones.*—In regard to the ferruginous material which occupies the interstices of the brown sandstones of America, it is important to notice, that, in the ochreous sands of Tertiary age and of the Drift, along the Appalachian border, this ferruginous cement appears to consist largely, perhaps chiefly, of *turgite:* that in the sandstones, both of the Triassic and of the Carboniferous, its chief component is *limonite:* but, in the Silurian beds, *e. g.*, the Shawangunk grits of Ulster Co., New York, the Potsdam sandstones on the shores of Lake Champlain, and the sandstones of the southern shore of Lake Superior, its bright, brick-red color and small loss of weight by ignition indicate its anhydrous condition and general identity with *hematite.* This last-mentioned state of the ferric oxide in the oldest of the Palæozoic sediments has been probably connected with their frequent deep subsidence and subjection to high thermal conditions. It is doubtless to derivation from the ground-up substance of these rocks that the red hard-pan of the drift of Minnesota and the surrounding region owes its iron-oxide, which, as N. H. Winchell points out,[275] exists in the anhydrous condition, while in the later clays the oxide is hydrated.

It therefore appears that the cementing iron-oxide in the ferruginous sandstones of each period exists *mainly* in the same state of hydration as the associated ores of *contemporaneous* origin. For the indigenous iron-ores of the Silurian, *e. g.*, in northern New York, Pennsylvania, Virginia, etc., and even yet a part of those of Archæan terranes, exist in the form of hematite; limonites afterwards predominate down to the Mesozoic; while in Tertiary and recent times, turgite is a characteristic accompaniment of other bog-ores.

[273] N. H. Winchell, Proc. Am. Assoc. Adv. Sci., 1875, Pt. II, 43, and Geol. and Nat. Hist. Surv. Minn., 1875, 62.

[274] Geol. of N. H., III, Pt. I, 338.

[275] Geol. and Nat. Hist. Surv. Minn., 1876, 158, 172, and 1878, 85.

The differences in physical characteristics now obtaining in the sandstones of this class, under our observation, seem to be due but partially to those of the primitive mechanical sediments. They have probably had a twofold origin: first, in the most ancient sediments, by subjection to the extensive chemical action of the organic acids washed down from the swamps of the Archæan highlands: secondly, in the later sediments, by subjection to the same feeble but long-continued chemical action, since their elevation above the sea-level. Most of these rocks may be therefore considered as species illustrating one of the following stages in the process:

1. Green or gray detrital ("argillaceous") sandstones and flags, the original sediments derived from the degradation of crystalline rocks, passing into the "arkose" variety, where the latter are highly feldspathic and micaceous.

By the contraction of the uplifted Archæan area, in the Devonian and later ages, and consequently of the extent of humus-covered surface, the rate of chemical decomposition of detritus could not compete with that of the mechanical disintegration of fresh material: the resulting heavy accumulation of unaltered rock-detritus is well represented by the green flags and grits of the Devonian basins of central New York, etc.

2. Brown or red ("ferruginous" or "ochreous") sandstones. These comprise, almost exclusively, the vast accumulations of upper Devonian, Carboniferous, and later ages; and because still more rapidly and loosely aggregated and more porous than the preceding species, they are now found with their *silicated* mineral components in a partially altered condition. Thus they pass, by mottled or striped varieties, into

3. White ("siliceous") sandstones. These may thus find one source of derivation at the end of the process of exhaustion of originally argillaceous or ferruginous sandstones by percolating solutions of organic acids. But, on the other hand, the *most ancient* sandstones, those of Silurian and pre-Silurian age, as well as nearly all Silurian and Archæan quartzytes, whose strata mostly rest upon the flanks of broad terranes of Archæan rocks, appear to be made up of porous siliceous sediments which have been more or less thoroughly acid-washed during Archæan time. Familiar examples of these latter rocks are presented in most of the Potsdam sandstones, contiguous to extensive Archæan areas. It is stated in reference to the Potsdam that "the waters were shallow,

and that there were beyond doubt coasts and exposed sand and mud flats," with crustaceans crawling above the sea-level, indications of dunes, etc. Nevertheless it has been considered "an age without land vegetation to bind the soil," and that "there was no green herbage over the exposed hills."[276] However, the ferruginous and the purely siliceous sands, both indicate, in my opinion, the work of organic acids in the transport and exhaustion of iron-oxide; and it may be that the foraminiferal life, suggested by the glauconite of the period, also implies, for its nutrition, that trace of organic matter dissolved in the ocean, which must then as now have been largely derived from vegetation upon the land and along the shores. The coast at that period, like the margin of the North American continent at present, seems therefore to have been marked by a continuous fringe of land and tidal marshes for the partial purification of the loose detritus and the concentration of the pure siliceous sands in the outer beach, thence to be strewn over the bottom of the ancient sea.

XX. Conclusion.

The consideration of this subject at so great a length has seemed desirable on account of the prevailing disregard of the doubtless feeble and slowly working organic solvents, to which, in large part, such results may now be attributed. Yet the exclusive presentation, in this paper, of this single group of agents, may lead to the equally unfounded conclusion that the present writer, in his turn, has disregarded the efficiency, in many of the geological phenomena discussed, of the other well-known chemical agents of inorganic origin and nature. For the present, perhaps, no certain conclusions can be reached, in such cases, till more numerous and careful experimental researches shall have acquainted us with the precise genesis, character, and transformations of these substances. My present purpose has been chiefly to modify the views of those, who, like Bischof, look upon the main work of organic matter in nature as one of mere reduction, and who assign to carbon dioxide an exaggerated importance in that of solution.

My grateful acknowledgments are due to Mr. W. G. Baker, the librarian of the School of Mines, Columbia College, New York, and to Mr. R. Little, the Superintendent of the Astor Library, for special privileges and kind assistance.

[276] Dana, *op. cit.*, 196, 200, 203.

On the Conditions to be filled by a Theory of Life. By Charles Sedgwick Minot, of Boston, Mass.

[ABSTRACT.]

It has been so often asserted that the essential nature of life cannot be discovered by man, that the remark has become commonplace. It would seem that this assertion is merely the assumption of haste, and is based only upon our present ignorance of vital properties. It should rather be said that the main object of all botanical and zöological studies is ultimately to discover the vital principle. The conviction that such is the end of biological research has led me for several years past to endeavor to sort out those vital phenomena which are most universal, in order to determine what are the principal and essential functions of living bodies. Such a labor cannot add much that is new to science, but it forced me to the conclusion that the favorite speculations of the present time concerning the origin and nature of life as explained by science were superficial and even crude, principally because they were not based upon a careful examination of the phenomena to be explained. In order to avoid erroneous opinions I have deferred publication for a long time, during which, however, no very essential improvement of the outline I had drawn has occurred to me. To deal with such difficult and dangerous questions with complete success requires more knowledge and judgment than I possess; I hope, therefore, to be allowed to publish what follows rather as opinions I deem plausible, than as conclusions I believe certain. Of one thing, however, I feel sure—that it is useless to discuss the opposing claims of conscious automatism, the mechanical theory of life and a vital principle, until we decide what are really the vital phenomena to be explained.

All the higher animals and plants are known to consist of colonies of cells. There are beside many unicellular animals and plants. Of late years there have been described a large number of organisms stated to consist solely of protoplasm. It is on these discoveries that the various protoplasm theories of life have been founded. Many popular articles have been written beginning with the assertion that protoplasm is a simple, jelly-like mass, and ending with the conclusion that life depends solely on the mechanical properties of protoplasm. I think it cannot be

too seriously regretted that respectable periodicals have published so many of such articles, because all but the ignorant know that protoplasm is not jelly-like, and not simple; on the contrary, it consists of many and very various chemical compounds, and from recent investigations it has become probable that it never exists as a homogeneous mass, but always contains numerous vacuoles, each enclosing some distinct substance or substances, liquid or solid; this structure explains the appearance of the so-called protoplasmatic network. Moreover, protoplasm probably can not permanently maintain its life when separated from a nucleus.[1] The number of protoplasmatic animals supposed to be without nuclei has rapidly diminished,—especially as the nucleus of the Foraminiferæ has been discovered, and the unicellular nature of the Infusoria established. To say that all the supposed protoplasmatic animals have a nucleus is not yet safe, but it must not be forgotten that in many cases the nucleus is discoverable when properly searched for with the aid of nice histological methods, and that those cases where it has not been found as yet are all cases of uncertainty, partly because careful observations have not been made, partly because the objects themselves are too minute. The probability, therefore, is against the separate existence of protoplasm, and is in favor of the universal presence of the nucleus. This view is strengthened by the discovery of the real nature of Bathybius

A cell must, therefore, be regarded as the unit of life, and the problem we are considering becomes to determine the general properties and functions of cells. I reason chiefly upon the basis of zöology, that branch of biology, which alone I have studied scientifically. The principal peculiarities of cells, as thus determined, I consider to be as follows:—

1. *Irritability.* When some motion strikes the cell it may simply act mechanically or give rise to peculiar effects which occur only in living matter. Nothing but some mode of motion ever acts as a stimulus. The effect produced by stimuli is a sensation. The stimuli may come from the outside or from the inside of the cell. The ultimate effects of the irritation may be inhibited,—that is delayed or prevented by the cell itself.

[1] By this I mean only, that *all* vital functions cannot be performed, because to some of them the nucleus is necessary. Of course protoplasm may remain alive when separated from the nucleus, but the possibility of reproduction is probably lost.

2. *The power of doing work*, or developing in response to a stimulus, or from some other cause, a certain amount of motion or energy. The work done may be mechanical, electrical, calorific or even luminiferous. The power of doing work cannot be sustained indefinitely, hence the phenomena of fatigue or exhaustion, and recovery.

3. *To set free energy by chemical changes;* each cell must be supposed to maintain a vortex by which matter is continually drawn in from the outside, the elements re-combined, and finally *in part* ejected, while the shape of the vortex or cell is preserved.

4. *Growth.* The cell retains permanently a portion of the matter drawn in by the vortex.

5. *Multiplication.* The cell cannot grow beyond a certain limit, but instead of further enlargement it divides. (The budding of Infusoria is only a peculiar form of cell division.)

6. *Senescence.* With each successive generation of cells the power of growth diminishes. Were this otherwise, the growth of each invividual at any given time would be in geometrical progression. This loss of power I term senescence.

7. *Rejuvenation.* The effects of senescence are overcome by some of the cells separating in character from the rest, and giving rise to peculiar bodies, the eggs and spermatozoa. A new cycle of cell generations is thus formed. In each cycle there is a slow senescence terminating in the formation of a new cycle by the rejuvenating influence of the sexual products.

8. *Material continuity of life.* The actual continuity of living matter is unbroken in consequence of the nature of cell division and of the origin of the sexual products. We cannot, therefore, yet conceive the origin of life, especially as all attempts to demonstrate spontaneous generation have been unconvincing.

9. *Heredity.* Every cell inherits the qualities of its parents, though imperfectly. The resemblance of an animal to its parent is due to the fact that a given cell of the parent cycle transmits an influence to the child cycle, tending to cause a similar cell to be developed in the same place and at the same time in the offspring. Heredity is imperfect, both inherently and from the effects of external circumstances.

10. *Direct influence of external circumstances.* This has now become established in several cases.

11. *Predetermined union of cells.* When the cells of one cycle

unite to form an animal, they arrange themselves definitely in three sets, (germ layers), at least in the higher metazoa.

12. *Vital union of cells.* Some of the cells of each set are united by means of the nerves into a common neural union or association, each member of which loses some of its originality and independence as an individual cell, and becomes able to affect the other members of the union both in their growth, nourishment, and sensations.

13. *Teleological mechanism.* This principle has been recently clearly formulated by Pflüger,—a need causes its own satisfaction, *e. g.*, the need of digestion produced by the presence of food causes the secretion of the digestive fluids.

14. *Memory.* Man knows by introspection that he has memory; we attribute it to the higher animals by common consent, and there is no reason for denying its existence in the lower forms. Real memory implies consciousness, otherwise it cannot be known that the sensation refers to the past.

15. *Habit.* This may be best defined as unconscious memory. It seems to me a grave error to identify habit and real memory. Habit implies that acts become easier if repeated.

16. *Consciousness.* Our knowledge of this, as of memory, is introspective, and is attributable to animals for the same reasons.

17. *Free will.* If there be such a thing it must of course be entered here.

These are the essential categories of the phenomena of animal life, and as they are all performed by colonies of cells, they must be the work of the units of such colonies, or in other words each one of these properties is that of a cell. There are reasons for thinking that unicellular animals have the same properties. To summarize, every cell performs all functions:—

1. Responds to stimuli.
2. Maintains the vortex.
3. Grows and divides.
4. Inherits, varies and bequeathes.

Further, each cell probably has

5. A sexual power, usually dormant.
6. Consciousness.
7. Memory.
8. Habit.

To explain life we must discover why it displays itself only in a physical basis composed of various albumenoid molecules, imbibed with water and certain salts, and commingled with other complex organic compounds, all disposed in a definite order; why this basis divides into distinct masses, cells, grouped each around a distinct body, the nucleus; why chemical and physical events take place in a particular order in each cell, the regulating power being within the cell itself; why senescence and rejuvenation take place; and finally the sources of consciousness, memory and habit. No mechanical explanation, or theory of conscious automatism suffices, but a vital force is the only reasonable hypothesis; the nature of that force is, for the present, an entire mystery, and before we can expect to discover it we must settle what are the phenomena to be explained by it.

On the Occurrence of Microscopic Crystals in the Vertebra of the Toad (*Bufo Americanus*). By H. Carrington Bolton, of Hartford, Conn. With a Note by Alexis A. Julien, of New York.

The microscopic crystals contained in the capsules attached to the spinal nerve of the frog have been examined by many Histologists. They were first noticed, we believe, by the learned Flemish physician, Blasius[1] in the latter part of the seventeenth century. Swann, in his *Comparative Anatomy of the Nervous System*,[2] gives figures of them without any detailed description, and Wagner[3] refers to the crystals as follows: "The ganglia admit of being very readily demonstrated, lying upon the sides of the vertebral column; they are situated near those small white vesicles which protrude by becoming swollen, chiefly during the spring of the year, and contain numerous microscopic calcareous

[1] Anat. Animalium, Amst. p. 291, 1681.
[2] Plate VII, figs. 5 and 6.
[3] Comp. Anat. Vertebrates, part I., p. 151.

crystals." They were also observed by Stannius and by Prof. Owen, who, however, added little to our knowledge of them.

In 1852 Dr. Jeffries Wyman prepared a memoir on the "Anatomy of the Nervous System of *Rana pipiens*," which is published in the fifth volume of the Smithsonian Contributions to Knowledge (1853). In this paper he states that the "crystal capsules are subject to some variety, but exist on the trunks of all the true spinal nerves, the hypoglossus included, and invest them more or less completely at their exit from the spinal canal, occupying the space between the transverse processes of two adjoining vertebræ. The capsule is a very thin membrane, sometimes having a diameter of 2 to 3 lines; its surface is minutely lobulated in appearance, which results from the existence of numerous partitions within, forming many small cavities, which communicate, though not very freely, with each other. The contents of these pouches are vast numbers of exceedingly minute crystals of a somewhat oval form, pointed at their extremities, and comparable in shape to a lemon seed, but sometimes presenting well defined angles."

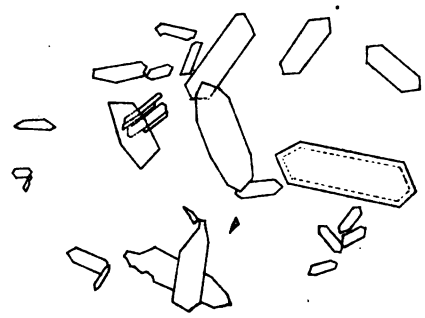
Dr. Wyman failed to confirm Wagner's statement that the capsules are more swollen in the spring of the year, having, he says, "detected them of nearly equal dimensions at all seasons," and he also differs from Stannius in regarding them as characteristic of the adult animal.

Dr. Wyman then remarks: "Dissections of other than Raniform Batrachians have not led to their detection; I have not found them in *Siren*, *Menobranchus*, *Bufo* or *Salamandra*, but have seen them in *Rana fontinalis*, *Rana halecina* and *Rana palustris*. They seem to be in these species constant appendages to the spinal nerves."

Notwithstanding this positive statement of so distinguished and accurate an observer, the writer has found the microscopic crystals in the toad in great abundance, and differing little in form and general appearance from those occurring in the frog. Specimens of the common toad (*Bufo Americanus*), collected both in the autumn and in the spring were dissected, and in every instance the contents of the spinal canal examined under a $\frac{1}{5}$ inch objective, disclosed the white matter as a mass of minute crystals.

On treating the crystals on a glass slide with acetic acid they dissolve with effervescence, and the addition of oxalate of ammo-

Fig.1 (RANA)



× 900 diam.

Fig.2. (BUFO)

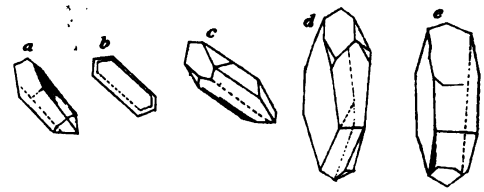
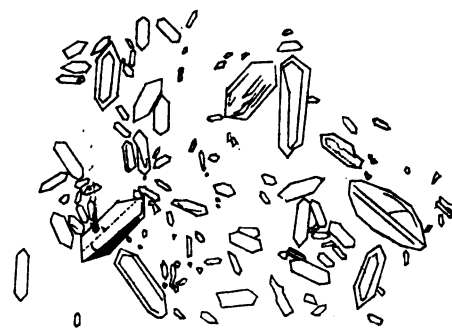


Fig.3. (BUFO)



× 1008 diam.

THE HELIOTYPE PRINTING CO 126 PEARL ST BOSTON

nium to this solution produces a milkiness visible to the unaided eye, which under the microscope appears to be formed of minute ovoid masses characteristic of precipitated calcium oxalate.

When the calcareous crystals are placed under the microscope in a drop of water, they exhibit in a marked manner the phenomena known as Brownian motions; the larger crystals remain at rest but the smaller ones having a length of about $\frac{1}{1000}$ millimetre maintain a constant restless motion. That similar crystals from the spinal canal of the frog exhibit this phenomenon is well known to histologists.[4]

The resemblance of the crystals from the toad to those from the frog is very close, but a careful examination shows that the former average somewhat smaller than the latter. Slides containing crystals from Rana and Bufo, mounted in Canada balsam, were submitted for accurate measurements to my friend, Mr. Alexis A. Julien, to whom I am greatly indebted for a painstaking examination.

Mr. Julien reports as follows:

"The crystals appear perfectly colorless with sharp outlines and with a refractive index so nearly that of the Canada balsam in which they are mounted that it is difficult to distinguish any but their outer edges. It will be seen by the measurements given below that the average size and the variation in size of the Bufo crystals are the greater of the two. In the accompanying sketch, Fig. 2, *d*, represents one of the larger of these crystals, exhibiting most distinctly the highly modified edges. In both the Rana and the Bufo crystals many were observed which at first glance displayed a curved or spindle-shaped outline tapering rather suddenly toward either end; some of these are shown in Figs. 1 and 3. They are often of considerable size and by careful focusing these curved outlines were found to consist of a succession of straight edges, indicating simply a more highly modified form of the common crystals. On the whole the crystals of both Rana and Bufo appear to me to differ from the otoliths of aragonite enclosed in the human ear, familiar to histologists, and to resemble rather highly modified rhombohedra of calcite belonging, perhaps, to the type represented in Fig. 553 of Dana's System of Mineralogy. No twins were anywhere observed."

[4] Frey's Microscopical Technology, translated by Dr. Geo. R. Cutter, p. 101 (1872).

Size of Crystals in fractions of millimetre.

Bufo.	Length.	Breadth.
Largest	0·033	0·0140
Smallest	0·0005	0·0003
Common size	0·0034 to 0·025	0·001 to 0·01.
Rana.		
Largest	0·0229	0·0074
Smallest	0·0007	0·0004
Common size	0·0068	0·0014

[Otoliths measure about 0·012 mm. long by 0·008 mm. broad.[5]]

The accompanying figures from drawings by Mr. Julien show the crystals as seen with a magnifying power of 900 to 1008 diameters, under the camera lucida.

Fig. 1 shows a portion of the field seen in the slide of Rana crystals and Fig. 3 shows the same in that of Bufo, with the usual intermixture of perfect crystals and irregular fragments. Fig. 2 contains several individual crystals enlarged in the drawing.

POSTSCRIPT. — MAY, 1880.

SINCE preparing the foregoing notes Mr. Simon H. Gage, Instructor in Physiology at Cornell University, has had the kindness at my suggestion to extend the examination for calcareous crystals to other Amphibia. He reports as follows:

"Alcoholic specimens of Siren and Menopoma were very carefully examined, but no crystals could be found either in the neural canal or on the spinal nerves. A fresh Menobranchus was examined with the same result."

Mr. Gage confirms our observation as to the occurrence of the crystals in Bufo and in this connection remarks:

"In Rana the crystals on the nerves are beyond, peripherad of, the ganglion and seem to have no connection with those lining the neural canal; while in Bufo the ganglion is completely surrounded by a cushion of crystals which seem to be merely a lateral extension through the intevertebral foramina of the general cushion lining the neural canal.

Dr. Wyman in the paper quoted makes no reference to the crystals in the neural canal of Rana."

Mr. Gage's communication is accompanied by a cross-section of the spinal column of Bufo showing the exact position of the cushion of crystals, and we regret that circumstances prevent a reproduction of his sketch.

[5] Dr. J. B. St. John Roosa in Diseases of the Ear, p. 475 (1874).

On Certain Forms of Muscæ volitantes. By J. W. Osborne, of Washington, D. C.

[ABSTRACT.]

The author stated that the occurrence of entoptic figures in their various forms had been so fully treated by Helmholz, that it was unnecessary to say anything on the general subject. It might be worth while, however, as he had for nearly seven years devoted considerable attention to the appearance of certain of these figures in his own eyes, to put on record a few facts concerning them, and to submit to the section a drawing of three distinct and permanent groups.

Fig. I is visible in the left eye and can be almost always found when wanted; nevertheless to draw it correctly was a matter of great difficulty, because it does not lie in the line of direct vision, and the effort to examine it drives it farther off. This group consists of eight nuclei, without any visible connection, but remarkably permanent in their relative positions.

In the diagram it is drawn twice. The figure to the left may be called normal, it being that which it most frequently assumes, and that to which any modification of its general outline invariably reverts. At the same time it is not unfrequently found folded up, as in the right hand drawing, and even to an extent greater than is there shown. This folded condition was most common at the time of first waking in the morning. The unfolding was usually somewhat sudden, and has several times been actually seen. Since this figure was first accurately noted, it has made a partial revolution in the direction of the hands of a watch; that is, a line through it, which about seven years ago was perpendicular, would now be inclined about 45°. This change was exceedingly gradual, and apparently uniform. The angle which this figure subtends is in the vertical direction about $4\frac{1}{2}°$; but this is not constant; nor is the definition of the image on the retina uniformly sharp.

Fig. II, visible in the right eye, represents a remarkable group. The three nuclei forming the right hand portion are frequently seen. When they are found, the two towards the left can always be found also, although an effort is generally necessary. The two above are exceedingly difficult to find. It is only by persistent effort, and an exact knowledge of the part of the field where they

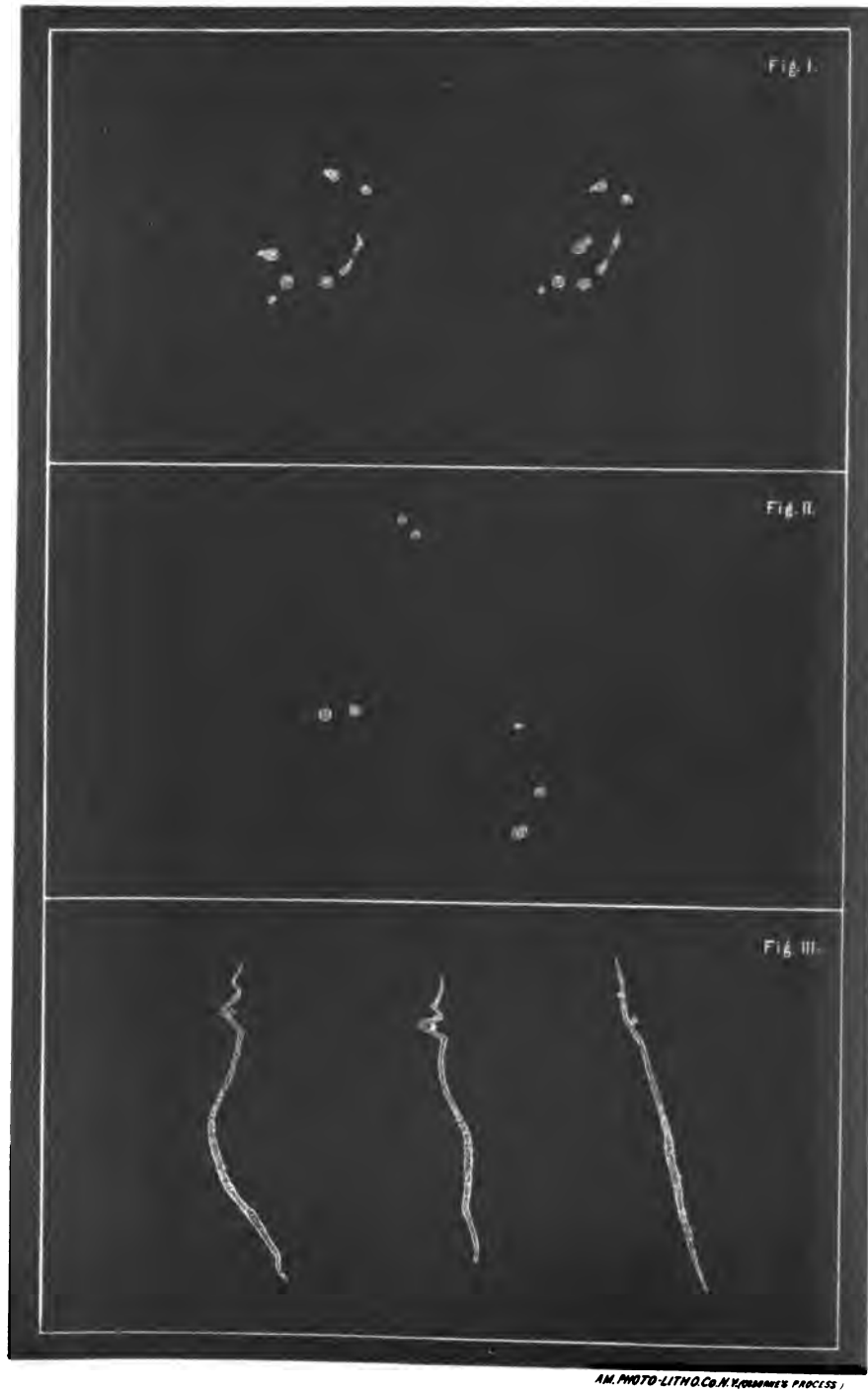
are situated that this is possible; and when they are found the three to the right usually become invisible.

Still, the left and upper pairs of nuclei sometimes come into the field of vision spontaneously, and on comparatively rare occasions all seven nuclei have been seen together moving as a whole. The difficulty of examining this group is due to the great distances between the nuclei, the whole figures covering a space of about $5\frac{1}{2}° \times 7\frac{1}{2}°$. No trace of connection has ever been observed between the units forming it, although their relative positions are very constant.

Fig. III is connected throughout; it belongs to the right eye. It is chiefly interesting from the fact, that flexures in it are very frequently seen, while it is floating through the field of vision, and the angular bendings of the upper end always occur at certain fixed joints. The three aspects given in the drawing show these peculiarities. It should also be remarked that both extremities of this figure have at times been developed very considerably in length; but for intervals of time so short, that it has been found impossible to draw them.— All these entoptic groups belong to the luminous species. Of them all it may be said that their relative position to the line joining the two eyes is constant, however the head may be inclined.

With regard to the movements of the muscæ volitantes, the author again referred to Helmholz, and to the researches of Donders and Doncan, but expressed the opinion that something yet remained to be done to make the received explanations quite satisfactory. The subjective impression was the combined result of the movements of the eye-ball, of the contained vitreous humor, and of the proper motion of the musca itself. To disentangle the last named was not easy; but when attempted the result seemed to indicate that actual motion was very rapidly imparted to the suspended particle of matter (which in a perfectly full and closed vessel it will be found impossible to imitate), and the acquired momentum seemed also disproportionate in amount, to that due to any probable difference in the specific gravity of the particle and that of the medium by the intervention of which the impulse was imparted.

ENTOPTIC GROUPS.



A.M. PHOTO-LITHO. Co. N.Y. (GUMMER'S PROCESS.)

The Inter-articular Ligament of the Head of the Ribs in the Cat. By S. H. Gage, of Ithaca, N. Y.

Synonymy.—1. Ligament interarticulaire.—*Bichat.* 2. Ligamentum teres.—*Gurlt and Schwab.* 3. Ligamentum conjugale costarum, and ligamentum teres.—*Meyer.* 4. Ligament interosseux ou interarticulaire.—*Rigot.* 5. Ligament articulaire.—*Chauveau.* 6. Ligamentum teres.—*Leyh.* 7. Ligamentum conjugale costarum.—*Cleland.* 8. Interarticular ligament.—*Human Anatomists.*

Note.—The works on papers in which these names are given are as follows:—Bichat, Xav.—Traité d'Anatomie descriptive, 1801, tome I, p. 231. Schwab—Anatomie der Hausthiere, 1821. Gurlt.—Vergleichende Anatomie der Hausthiere, 1822, und Anatomie des Pferdes, 1832. Meyer, A. F.—Ueber ein neuentdecktes Band, Jochband der Rippen. Muller's Archiv für Anatomie, Physiology, etc., 1834, s. 273. Rigot.—Traité complet de l'Anatomie des Animaux domestique, 1840. Chauveau, A.—Traité d'Anatomie comparée des Animaux domestiques. Leyh, A. F.—Handbuch der Anatomie der Hausthiere, etc. Cleland, John.—On the structure, actions and morphological relations of the ligamentum conjugale costarum. Edinburgh new Philosophical Journal, April, 1859.

Structure in the Cat.—In the domestic cat (*Felis domestica*), the heads of the ribs of the second to the eleventh pairs inclusive are united across the middle line of the body in the following way: Arising from about the middle of the head of the rib is a very strong and dense ligament, reminding one of the ligamentum teres of the femur. If the ligament be traced, it will be found to extend across the middle line of the body and attach itself to the head of the opposite rib. In its passage from one side of the body to the other, this ligament traverses the floor of the neural canal, resting in a groove formed on the dorsal aspect of the intervertebral cartilage. In its passage through the neural canal, it is roofed over by the posterior common ligament so that it is not visible until that is removed. Following Bichat, this ligament will be called *interarticular*, as it is without doubt only a modification of the interarticular ligament in man.

In order to study the structure and relations of this ligament in detail it is best to take one of the middle pairs of ribs, the sixth

pair for example, as its development and characteristics are most strongly marked in this region.

The articular part of the rib is pear-shaped, the small end pointing ventrad. Near the middle of this articular surface is a marked depression, as large proportionally as that in the head of the femur for the ligamentum teres. The main bundle of the interarticular ligament arises from this; but a moderately thin part arises from the head between the main part and the capsular ligament. This part is very closely connected to the capsular ligament, and seems to be an offset from it. The fibres of the ventral part of the interarticular ligament are at first directed nearly dorsad, and then extend toward the opposite rib.

In the groove on the dorsal side of the intervertebral cartilage, the ligament becomes flattened, and is attached by loose fibres to the posterior common ligament and by somewhat denser fibres to the intervertebral cartilage. The surface resting in the groove is free and smooth, and both it and the groove are lined by an extension of the synovial membrane of the heads of the two opposite ribs. It follows from this description that the joints of a pair of ribs are connected; and the two articular facets on the head of the same rib are in communication with each other, as each communicates with the groove for the interarticular ligament.

The *stellate ligament* is so attached to the head of the rib that it aids the interarticular ligament in dividing the head into two parts, corresponding to the articular facets for the two vertebræ to which it is joined. Many of the fibres of this stellate ligament pass across to the opposite rib, going beneath the anterior common ligament as the interarticular passes beneath the posterior common ligament. There is no groove, however, and the cross band is very intimately connected to the intervertebral fibro-cartilage.

COMPARISON WITH MAN. — If the interarticular ligament in the cat be compared to the homologous structure in man, a marked difference will be seen. In man the ligament is plate like, and joins the intervertebral fibro-cartilage without sending fibres across the middle line to the opposite rib. It also completely separates the two articular facets on the head of the rib, so that each is lined by an independent synovial membrane. In the cat, not only do the two facets of the same rib communicate with each other, but they communicate with the groove of the interarticular ligament, and through this groove, with the joint of the opposite rib. That is,

there is but one synovial cavity in the cat, and four in man, for a single pair of ribs.

COMPARISON WITH THE LOWER MAMMALS.—In comparing the cat's interarticular ligament with that of the lower mammals, it is found to differ from the seal in being but partly free, whereas in the seal it is entirely surrounded by synovial membrane (*Cleland*). In the horse, part of the ligament joins the intervertebral cartilage instead of all going across to the opposite rib as in the cat (*Meyer*).

In the woodchuck, some of the ribs have the ligament fully developed, and all of it crosses to the opposite side as in the cat, while with others, part of the ligament joins the intervertebral cartilage as in the horse.

Finally, in the musk rat the greater part of the fibres are attached to the intervertebral cartilage; but some of them pass across under the posterior common ligament to the opposite side. There is no groove developed, however, and the transverse fibres are very closely connected on all sides, as were the transverse fibres in the stellate ligament of the cat.

List of animals in which the interarticular ligament has been observed.—Man (*Bichat*). Monkey and rabbit, as in man (*Meyer*). Dog, cat, fox, wolf, bear, badger, horse, ox and pig[1] (*Meyer*). Sheep (*Chauveau*). Lion, otter, seal, weasel and squirrel (*Cleland*). Kangaroo, as in man (*Cleland*).

Leopard (*Felis leopardus*), mink (*Putorius lutreolus*), raccoon (*Procyon lotor*), musk rat (*Fiber zibethicus*), woodchuck (*Arctomys monax*) the author.

FUNCTIONS.—The office of the interarticular ligament seems to be solely to hold the heads of the ribs in position. So strongly is it developed in the cat, that the head of the rib will often break before the ligament will give way.

The reason for the extension of the band across the middle line from rib to rib, seems to be, first, to give more freedom of motion to the ribs, and second, and most important, to avoid the strain upon the intervertebral fibro-cartilage that would result in violent inspiration if the ligament were attached directly to it as in man, rabbit, etc.

Prof. Meyer, in explaining the functions of the interarticular ligament, says that in animals like man and the rabbit, where the

[1] Dr. Cleland says "in the pig none of the fibres of the interarticular ligament are prolonged to the opposite side." In my own observations, I could find no fibres crossing from one side to the other. Is this peculiar to German pigs?

fibres do not pass from side to side, it serves merely to hold the head of the rib in the articular cavity. Where, however, it passes from the head of one rib to its fellow on the opposite side, it serves to hold the heads of the ribs in the same relative position, and to prevent the too great lateral expression in violent inspiration; and the generalization is made that its development is directly proportional to the amount of twisting (*Drehbewegung*) of which the spinal column is capable. It is evident from the position of the articular facet for the tuberosity of the rib, and the corresponding facet on the transverse process of the vertebra, that any structure tending to hold the head of the rib in position, would prevent lateral motion of the ribs beyond a certain degree. Where the ligament joins the heads of two opposite ribs, the strain is confined mostly to the ribs themselves, and does not involve the intervertebral fibro-cartilage as in animals where the ligament is attached directly to it.

His generalization, with reference to its proportional development in animals capable of a great deal of twisting of the spinal column, does not seem to hold; for it is very strongly developed in some, as for example the horse and ox, in which the movements of the spinal column are comparatively limited; and on the other hand it is absent as a cross band in the rabbit, and in monkeys. It certainly seems, if his generalization were correct, that a rabbit stands in greater need of the ligament than its near relative, the clumsy woodchuck.

One reason for preparing this paper was to correct the statement of Prof. Meyer, that in the cat only eight pairs of ribs (3–10 inclusive) possess this ligament. The fact is, with American cats at least, that the ligament is present in ten pairs (2–11 inclusive).

The more especial reason, however, was to call attention to the fact that Straus-Durckheim in his magnificent monograph of the *bones*, *ligaments* and *muscles* of the cat, published in 1845, nowhere mentions the existence of such a ligament. And in his figure of the ninth rib (plate XIII, fig. 17) the depression in the head of the rib for the attachment of the ligament is not shown.

This omission seems the more strange, as one, in nearly every instance, finds correct this retrospect placed on the title page of his great work—"I believe I have omitted nothing." The omission seems almost inexplicable also when it is considered, that Bichat had described the ligament in man, and Meyer and Rigot in animals, long before the work of Durckheim was published.

A New Method of demonstrating the Thoracic Duct in Animals. By S. H. Gage, of Ithaca, N. Y.

The thoracic duct or great lymphatic trunk which empties into the left subclavian vein may be demonstrated in three ways: —

1. The ordinary way, by feeding the animal with milk an hour or two before death.

2. By bleeding well, and then injecting the arterial system, while the animal is warm, with fine gelatin, colored with carmine or aniline. The lacteals and thoracic duct will, nearly always, be filled with the red gelatin.[1]

3. By feeding with milk as in the first case so that the receptaculum chyli may be easily found, and then injecting the duct from the receptacle with fine, colored plaster of paris. I am not aware that this method has been previously employed.

A Short Biography of the Menhaden. By G. Brown Goode, of Middletown, Conn.

The herring family is represented on the Atlantic coast of the United States by ten species, all of which swim in immense schools, and several, such as the sea-herring, the shad, and the various species of the river alewives, are of great economical importance.

In abundance and value these are all surpassed by the menhaden, *Brevoortia tyrannus* (*Latrobe* — Goode), a fish whose habits are in many respects anomalous, and concerning which very little has been known and written.

The menhaden has at least thirty distinct popular names, most of them limited in their use within narrow geographical boundaries. To this circumstance may be attributed the prevailing ignorance among our fishermen regarding its habits and migrations which has perhaps prevented its more extensive utilization, particularly in the South.

[1] This fact was first noted by Meckel, and reported by X. Bichat in the Anatomie générale, 1812, t. II, p. 581.

North of Cape Cod the name of "pogy" is almost universally in use, while in southern New England the fish is known only as "the menhaden;" these two names are derived from two Indian words of the same meaning; the first being the Abnaki name "pookagan," or "poghaden," which means "fertilizer," while the latter is the modification of a word which in the Narragansett dialect meant "that which enriches the earth." About Cape Ann, "pogy" is partially replaced by "hard-head," or "hard-head shad," and in eastern Connecticut by "bony fish." In western Connecticut the species is usually known as the white-fish, while in New York the usage of two centuries is in favor of "mossbunker." This name is a relic of the Dutch colony of New Amsterdam, having evidently been transferred from the "scad," or "horse mackerel," *Garanx trachurus*, a fish which visits the shores of Northern Europe in immense schools, swimming at the surface in much the same manner as our menhaden, and known to the Hollanders as the "marshbanker." New Jersey uses the New York names with its local variations, such as "bunker" and "marshbanker." In Delaware Bay, the Potomac and the Chesapeake, we meet with the "alewife," "bay alewife," "pilcher" (pilchard) and "green-tail."

Virginia gives us "bug-fish," "bug-head," and "bug-shad," referring to the parasitic crustacean found in the mouths of all southern menhaden. In North Carolina occurs the name "fat-back," which prevails as far south as Florida, and refers to the oiliness of the flesh. In this vicinity, too, the names "yellow-tail" and "yellow-tailed shad" are occasionally heard, while in southern Florida the fish is called "shiner" and "herring." In South America among the Portuguese the name "savega" is in use. On the St. John's River, and wherever northern fishermen are found, "menhaden" is preferred, and it is to be hoped that this name will in time be generally adopted. A number of trade names are employed by the manufacturers in New Jersey, who can this fish for food; these are "American sardine," "American club-fish," "shadine" and "ocean trout."

In 1815 the species was described by Mitchell, of New York, under the name *Clupea menhaden*, which has since been commonly accepted. A prior description by Latrobe, in 1802, long lost sight of, renders it necessary, as I have elsewhere demonstrated, to adopt the specific name *tyrannus*. The genus *Brevoortia*, of which this species is the type, was established by Gill, in 1861.

The geographical range of *Brevoortia tyrannus* varies from year to year. For 1877 it was, so far as it is possible to define it in words, as follows: The wanderings of the species are bounded by the parallels of north latitude 25 and 45; on the continental side by the line of brackish water; on the east by the inner boundary of the gulf stream. In the summer it occurs in the coastal waters of all the Atlantic states from Maine to Florida. In winter only south of Cape Hatteras. The limits of its winter migration oceanwards cannot be defined; though it is demonstrated that the species does not occur about the Bermudas or Cuba, nor presumably in the Caribbean Sea. In Brazilian waters occurs a geographical race of the same species, *Brevoortia tyrannus*, sub-species *aurea*, the *Clupanodon aureus* of Agassiz and Spix; on the coast of Paraguay and Patagonia by *Brevoortia pectinata;* in the Gulf of Mexico by *Brevoortia patronus*.

With the advance of spring the schools of menhaden appear near our coasts in company with, and usually slightly in advance, of the other non-resident species, such as the shad, alewives, bluefish and squeteague. The following general conclusions regarding their movements are deduced from the statements of about two hundred observers at different points on the coasts from Florida to Nova Scotia.

At the approach of settled warm weather they make their appearance in the inshore waters. It is manifestly impracticable to indicate the periods of their movements except in an approximate way. The comparison of two localities distant apart one or two hundred miles will indicate very little. When wider ranges are compared there becomes perceptible a certain proportion in the relations of the general averages. There is always a balance in favor of earlier arrivals in the more southern localities; thus it becomes apparent that the first schools appear in Chesapeake Bay in March and April; on the coast of New Jersey in April and early May; on the south coast of New England in late April and May; off Cape Ann about the middle of May, and in the Gulf of Man in the latter part of May and the first of June. Returning, they leave Maine in late September and October; Massachusetts in October, November and December, the latest departures being those of fish which have been detained in the land-locked bays and creeks; Long Island Sound and vicinity in November and December; Chesapeake Bay in December, and Cape Hatteras in Janu-

ary. Farther to the south they appear to remain more or less constantly throughout the year.

A strange fact is, that their northern range has become considerably restricted within the past twenty-five years. Perley, writing in 1852, stated that they were sometimes caught in considerable numbers about St. John's, N. B., and there is abundance of other testimony to the fact that they formerly frequented the Bay of Fundy in its lower parts; at present the eastward wanderings of the schools do not extend beyond Isle Au Haut and Great Duck Island, about forty miles west of the boundaries of Maine and New Brunswick. They have not been known to pass these limits for ten or fifteen years. They have this year hardly passed north of Cape Cod, and forty or more steamers, which have usually reaped an extensive harvest on the coast of Maine, have been obliged to return to the fishing grounds of southern New England, where menhaden are found as abundantly as ever.

I have elsewhere shown the arrival of the menhaden schools to be closely synchronous with the period at which the weekly average of the surface temperatures of the harbors rises to 51° F. That they do not enter waters in which, as about Eastport, Me., the midsummer surface temperatures, as indicated by monthly averages, fall below 51° F., and that their departure in the autumn is closely connected with the fall of the thermometer to 51° and below. In 1877 a cold summer seemed to threaten the success of the Maine menhaden fisheries. In September and October, however, the temperatures were higher than in the corresponding months of the previous year, and the scarcity of the early part of the season was amply amended for.

The season of 1878 in Maine was fairly successful, the three summer months being warmer than in 1877, but cooler than in 1876. The absence of the menhaden schools north of Cape Cod, in 1879, is also easily explained by the study of temperatures, the water of the Gulf of Maine, as indicated by the observations made in Portland harbor. The averages for the three summer months are as follows, the numerator of the fraction being the average surface temperature, the denominator that of the bottom: 1876, 62.5–57.9; 1877, 58.5–56.7; 1878, 61.5–58.1; 1879, 56.1—54.6.

The average for the three summer months of 1879 is less than that of June, 1876.

This may perhaps be explained by a study of ocean temper-

atures. In August, 1878, there was a very rapid fall in the temperature of the surface, in the Gulf of Maine, so that the average temperature of that month was less than that of July, instead of being higher, as is usual. This may have had the effect of driving the fish into the warmer water of the bays and estuaries. The monthly averages for 1876, 1877, 1878, and 1879 are as follows:

1876—June, 56.9–54; July, 66.7–59.4; August, 63.9–60.4.
1877—June, 54.9–53.3; July, 58.1–56.3; August, 62.4–60.6.
1878—June, 56.8–55.2; July, 66.9–59.3; August, 60.7–59.9.
1879—June, 52.9–51.7; July, 55.9–54.1; August, 59.6–58.

The arrival of the menhaden is announced by their appearance at the top of the water. They swim in immense schools, their heads close to the surface, packed side by side, and often tier above tier, almost as closely as sardines in a box. A gentle ripple indicates their position, and this may be seen at a distance of nearly a mile by the lookout at the mast-head of a fishing vessel, and is of great assistance to the seiners in setting their nets. At the slightest alarm the school sinks toward the bottom, often escaping its pursuers. Sailing over a body of menhaden swimming at a short distance below the surface, one may see their glittering backs beneath, and the boat seems to be gliding over a floor inlaid with blocks of silver. At night they are phosphorescent. Their motions seem capricious and without a definite purpose; at times they swim around and around in circles; at other times they sink and rise. While they remain thus at the surface after the appearance of a vanguard they rapidly increase in abundance until the sea appears to be alive with them. They delight to play in inlets and bays, such as the Chesapeake, Peconic and Narragansett Bays, and the narrow fiords of Maine. They seem particularly fond of shallow waters protected from the wind; in which, if not molested, they will remain throughout the season, drifting in and out with the tide. Brackish water attracts them, and they abound at the mouth of streams, especially on the southern coast. They ascend the St. John's River more than thirty miles; the St. Mary's, the Neuse, the York, the Rappahannock, the Potomac, nearly to Washington, and the Pawtuxent to Marlboro. They come in with or before the shad, and are very troublesome to the fishermen by clogging their nets. I am not aware that this difficulty occurs in northern rivers, though they are found in the sum-

men in the Hudson and its tributaries, the Housatonic, Mystic, Thames and Providence Rivers, in the waters of Cape Cod, and at the mouth of the Merrimack. A curious instance of capriciousness in their movements occurred in the coast of Maine, where much harm was felt, because their tracks were thought to have been changed through the influence of seining. The same fishermen could obtain none for bait, and vessels followed them far out to sea, capturing them in immense quantities forty miles from land. The fisheries had produced no such effect south of Cape Cod, and it was quite inexplicable that their tracks should have been so modified in the north. In 1874, however, after ten years or more, they resumed their former tracks of hugging the shores, and the menhaden fishery of Maine was carried on, for the most part, in the rivers.

So conspicuous a prey to man, birds, and other fishes is not known. It does not appear to be for the purpose of feeding; perhaps the fisherman is right when he declares that they are playing.

An old mackerel fisherman thus describes the difference in the habits of the mackerel and menhaden: "Pogies swim differently from mackerel: the pogy slaps with his tail, and in moderate weather you can hear the sound of a school of them, as first one and then another strikes the water. The mackerel go along "gilling"—that is, putting the sides of their heads out of the water as they swim. The pogies make a flapping sound, the mackerel a rushing sound. Sometimes in calm and foggy weather you can hear a school of mackerel miles away." They do not attract small birds as do the schools of predaceous fish. The fish-hawks often hovers above them, and some of the larger gulls occasionally follow them in quest of a meal. About Cape Cod one of the gulls, perhaps *Larus argentatus*, is called "pogy gull."

On warm, still, sunny days the fish may always be seen at the surface, but cool or rainy weather and prevailing northerly or easterly winds quickly cause them to disappear. When it is rough they are not so often seen, though schools of them frequently appear when the sea is too high for fishermen to set their nets. The best days for menhaden fishing are when the wind is northwesterly in the morning, dying out in the middle of the day, and springing up again in the afternoon from the southwest, with a clear sky. At the change of the wind on such a day they come to the surface in large numbers.

A comparison of the weather upon the menhaden and the herring yields some curious results. The latter is a cold water species. With the advance of summer it seeks the north, returning to our waters with the approach of cold. The menhaden prefers the temperature of 60° or more; the herring 55° and less. When the menhaden desert the Gulf of Maine they are replaced by the herring. Cold weather drives the former to the warmer strata, while it brings the latter to the surface. The conditions most favorable on our coast for the appearance of herring on the surface, and which correspond precisely with those which have been made out for the coast of Europe, are least so for the menhaden.

Their winter habitat, like that of the other cold water absentees, has never been determined. The most plausible hypothesis supposes that instead of migrating toward the tropics or hibernating near the shore, as has been claimed by many, they swim out to sea until they find a stratum of water corresponding to that frequented by them during their summer sojourn on the coast.

This is rendered probable by the following considerations: 1. That the number of menhaden in southern waters is neither less in the season of their abundance, nor greater in that of their absence from the north coast. 2. That there are local varieties of the species, distinguished by physical characters almost of specific value, by differences in habits, and in the case of the southern schools, by the universal presence in the mouth of a crustacean parasite, which is never found with those north of Cape May. 3. That the same schools usually reappear in the same waters in successive years. 4. That their very prompt arrival in the spring suggests their presence in waters near at hand. 5. That their leanness when they first appear renders it evident that they have had no food since leaving the coast in autumn. The latter consideration, since they are bottom feeders, is the strongest confirmation of the belief that their winter home is in the mid-oceanic sub-strata.

As is indicated by the testimony of a large number of observers, whose statements are elsewhere reviewed at length, the menhaden is by far the most abundant species on the eastern coast of the United States. Several hundred thousands are frequently taken in a single draft of a purse-seine. A firm in Milford, Connecticut, captured in 1870, 8,800,000; in 1871, 8,000,000; in 1872, 10,000,000; in 1873, 12,000,000; in 1877, three sloops from New

London seined 13,000,000. In 1877, an unprofitable year, the Pemaquid Oil Company took 20,000,000, and the town of Boothbay alone 50,000,000. There is no evidence whatever of any decrease in their numbers, though there can be in the nature of the case absolutely no data for comparison of their abundance in successive years. Since spawning menhaden are never taken in the nets, no one can reasonably predict a decrease in the future.

The nature of the food of the menhaden has been closely investigated; hundreds of specimens have been dissected, and every stomach examined by me was found full of dark, greenish or brownish mud or silt, such as occurs near the mouths of rivers and on the bottoms of still bays and estuaries. When this mud is allowed to stand for a time in clear water, this becomes slightly tinged with green, indicating the presence of chlorophyl, perhaps derived from the algæ, so common on muddy bottoms. In addition to particles of fine mud the microscope reveals a few common forms of diatoms.

There are no teeth in the mouth of the menhaden, their place being supplied by about 1,500 thread-like bristles, from one-third to three-quarters of an inch long, which are attached to the gill arches, and may be so adjusted as to form a very effective strainer; the stomach is globular, pear-shaped, with thick muscular walls, resembling the gizzard of a fowl, while the length of the coiled intestine is five or six times that of the body of the fish. The plain inference from these facts, taken in connection with what is known of the habits of the menhaden, seems to be that their food consists in large part of the sediment, containing much organic matter, which gathers upon the bottoms of still, protected bays, and also of the vegetation that grows in such localities. Perhaps, too, when swimming at the surface with expanded jaws, they are able to gather nutritious food which floats on the water.

Their rapid increase in size and fatness, which commences as soon as they approach our shores, indicates that they find an abundant supply of some kind of food. The oil manufacturers report that in the spring a barrel of fish often yields less than three quarts of oil, while late in the fall it is not uncommon to obtain five or six gallons.

There is still some mystery about their breeding habits; thousands of specimens have been dissected since 1871 without the discovery of mature ova. In early summer the genitalia are quite

undeveloped, but as the season advances they slowly increase in size and vascularity. Among the October fish a few ovaries were noticed in which the eggs could be seen with the naked eye. A school of large fish driven ashore in November in Delaware Bay by the blue-fish, contained spawn nearly ripe, and others taken at Christmas time in Provincetown harbor, evidently stragglers accidently delayed, contained eggs quite mature. Young menhaden from one to three inches in length and upward are common in summer, south of New York, and those of five to eight inches in late summer and autumn in the southern part of New England. These are in schools and make their appearance suddenly from the open ocean like the adult fish. Menhaden have never been observed spawning on the southern coast and the egg-bearing individuals when observed are always heading out to sea. These considerations appear to warrant the theory that their breeding grounds are on the offshore shoals which skirt the coast from George's banks to the Florida Keys.

Several writers have lately expatiated on the vast fecundity of the menhaden; this has not yet been demonstrated. In a pair of immature ovaries I made out, by estimate, 10,000 eggs. A large mature fish would have many more, but in all probability the number never exceeds 40,000.

Among the enemies of the menhaden may be counted every predaceous animal which swims in the same waters. Whales and dolphins follow the schools and consume them by the hogshead; sharks of all kinds prey upon them largely; one hundred have been taken from the stomach of one shark; all the large carnivorous fishes feed upon them. The tunny is the most destructive. "I have often," writes a gentleman in Maine, "watched their antics from the mast-head of my vessel; rushing and thrashing like demons among a school of fish; darting with almost lightning-swiftness, scattering them in every direction, and throwing hundreds of them in the air with their tails." The pollock, the whiting, the striped bass, the cod, the squeteague and the gar-fish are savage foes. The sword-fish and the bayonet-fish destroy many, rushing through the schools and striking right and left with their powerful swords. The blue-fish and bonito are, however, the most destructive enemies, not even excepting man; these corsairs of the sea, not content with what they eat, which is of itself an enormous quantity, rush ravenously through the closely crowded

schools, cutting and tearing the living fish as they go, and leaving in their wake the mangled fragments. Traces of their carnage remain for weeks in the great "slicks" of oil so commonly seen on smooth water in summer. Professor Baird, in his well known and often quoted estimates of food annually consumed by the blue-fish, states that probably ten thousand millions of fish or twenty-five millions of pounds daily, or twelve hundred million millions of fish and three hundred thousands of millions of pounds are much below the real figures. This estimate is for the period of four months in the middle of the summer and fall, and for the coast of New England only.

Such estimates are professedly only approximations, but are legitimate in their way, since they enable us to appreciate more clearly the luxuriance of marine life. Applying similar methods of calculation to the menhaden I estimate the total number destroyed annually on our coast by predaceous animals at a million million of millions; in comparison with which the quantities destroyed by man, yearly, sink into insignificance.

It is not hard to surmise the menhaden's place in nature; swarming our waters in countless myriads, swimming in closely packed, unwieldy masses, helpless as flocks of sheep, near to the surface and at the mercy of every enemy, destitute of means of defence and offence, their mission is unmistakably to be eaten.

In the economy of nature certain orders of terrestrial animals, feeding entirely upon vegetable substances, seem intended for one purpose—to elaborate simple materials into the nitrogenous tissues necessary for the food of other animals, which are wholly or in part carnivorous in their diet; so the menhaden feeding upon otherwise unutilized organic matter is preëminently a meat-producing agent. Man takes from the water every year eight or nine hundred millions of these fish, weighing from two hundred to three hundred thousand tons, but his indebtedness does not end here: when he brings upon his table blue-fish, bonitoes, weak-fish sword-fish, or bass, he has before him usually menhaden flesh in another form.

The commercial importance of the menhaden has but lately come into appreciation. Twenty-five years ago and before, it was thought to be of very small value. A few millions were taken every year in Massachusetts Bay, Long Island Sound and the inlets of New Jersey. A small portion of these were used for

bait; a few barrels occasionally salted in Massachusetts to be exported into the West Indies. Large quantities were ploughed into the soil of the farms along the shores, stimulating the crops for a time, but in the end filling the soil with oil, parching it and making it unfit for tillage.[1] Since that time manifold uses have been found. As a bait-fish this excels all others; for many years much the greater share of our mackerel was caught by its aid, while the cod and halibut fleet use it rather than any other fish when it can be procured. The total consumption of menhaden for bait, 1877, did not fall below 80,000 barrels, or 26,000,000 of fish valued at $500,000. Ten years before, when the entire mackerel fleet was fishing with hooks, the consumption was much greater. The Dominion mackerel fleet buy menhaden bait in

[1] Professor Trumbull tells us that the Indian names of *Brevoortia*, "menhaden" and "poghaden" (pogy), mean "fertilizer," that which manures, and that the Indians were accustomed to employ this species, with others of the herring tribe (*aumsuog and munnawhateaug*), mostly the alewife (*Pomolobus pseudoharengus*), in enriching their corn-fields. Thomas Morton wrote in 1632, of Virginia: "There is a fish (by some called shadds, by some allizes) that at the Spring of the yeare passe up the rivers to spawn in the ponds, & are taken in such multitudes in every river that hath a pond at the end that the inhabitants doung their grounds with them. You may see in one township a hundred acres together, set with these fish, every acre taking 1,000 of them, & an acre thus dressed will produce and yeald as much corne as three acres without fish; & (least any Virginea man would inferre hereupon that the ground of New England is barren, because they use no fish in setting their corne, I desire them to be remembered, the cause is plaine in Virginea) they have it not to sett. But this practice is onely for the Indian maize which must be set by hands), not for English grain: & this is, therefore, a commodity there."

This passage is very interesting, showing the use of fish fertilizers in Virginia two hundred and fifty years ago or more, and, from what is known of the habits of the herring family in Virginia rivers and the persistency of local names, there can be little doubt that many menhaden were used among the fertilizing fish, though "shadds and allizes" doubtless includes the shad (*Alosa sapidissima*), the mattowocca (*Pomolobus mediocris*), the alewife (*Pomolobus pseudoharengus*), and the thread-herring (*Dorosoma cepedianum*, all of which are common in spring in the Potomac and other rivers which empty into Chesapeake Bay.

In Governor Bradford's "History of Plimoth Plantation" an account is given of the early agricultural experiences of the Plymouth colonists. In April, 1621, at the close of the first long dreary Winter, "they (as many as were able) began to plant their corne, in which service Squanto (an Indian) stood them in great stead, showing them both ye manner how to set it and after how to dress and tend it. Also he tould them, excepte they got fish & set with it (in these old grounds) it would come to nothing; and he showed them yt in ye middle of Aprill they should have store enough come up ye brooke by which they begane to build and taught them how to take it."

An allusion to the practice of the Indians in this respect may be found in George Mourt's "Relation or journal of the beginning and proceedings of the English plantation settled at Plimoth, in New England, by certain English adventurers both merchants and others." * * * * "London, 1622:" "We set the last Spring some twenty acres of Indian corn, and sowed some six acres of barley and peas, and, according to the manner of Indians, we manured our ground with herrings, or rather shads, which we have in great abundance and take with great ease at our doors. Our corn

quantity, and its value has been thought an important element in framing treaties between our government and that of Great Britain.

As a food resource it is found to have great possibilities. Many hundreds of barrels are sold in the West Indies while thousands of barrels are salted down for domestic use by families living near the shore. In many sections they are sold fresh in the market. Within six years there has sprung up an important industry which consists in packing these fish in oil, after the manner of sardines, for home and foreign consumption. In 1874 the production of canned fish did not fall below 500,000 boxes.

The discovery made by Mr. S. L. Goodale, that from these fish may be extracted, for the cost of carefully boiling them, a substance possessing all the properties of Liebig's "Extract of

did prove well, and God be praised, we had a good increase of Indian corn, and our barley indifferent good." * * * *

Again, in Edward Johnson's "Wonder-working Providence of Sion's Saviour in New England, Being a Relation of the firste planting in New England in the yeere 1628, London, 1654," written in 1652, the author says: "But the Lord is pleased to provide for them [the colonists] great store of fish in the Spring time, especially alewives, about the bignesse of a herring. Many thousands of these they used to put under their Indian corne, which they plant in hills five foot asunder; and assuredly when the Lord created thise corne, hee had a special eye to supply these his people's wants with it, for ordinarily five or six grains doth produce six hundred."

Menhaden do not appear to have been much used by agriculturists of Cape Cod in the beginning of this century, though the old record shows that the horse-shoe crab and sea-weed were extensively applied.

In 1792, the Hon. Ezra L. Hommedieu, of New York, published a paper in the New York Agricultural Transactions which gives somewhat more accurate data and directions concerning the use of fish as a fertilizer. He says: "Experiments made by using the fish called menhaden or mosbankers as a manure have succeeded beyond all expectation. * * * In dunging corn in the holes, put two in a hill, on any kind of soil where corn will grow, and you will have a good crop." He recommends them as a top-dressing for grass. "Put them on a piece of poor loamy land, at the distance of fifteen inches from each other. * * * And by their putrefaction they so enrich the land that you may mow about two tons per acre." But he adds very wisely: "How long this manure will last has not been determined." He gives in his quaintly interesting way, an account of "an experiment made the last Summer by one of my near neighbors, Mr. Tuthill, in raising vegetables with this fish manure," which is worth citing as an illustration of the curious combinations of truth and error, which, in their lack of definite knowledge of the laws of plant-growth and the action of manures, the theorizers of that time invented.

The following order from the records of the town of Ipswich, Mass., May 11, 1644, illustrates, in a comical way, the customs of using fish for manure in these early days:

"It is ordered that all doggs, for the space of three weeks after the publishing hereof, shall have one legg tyed up, and if such a dogg shall break loose and be found doing any harm, the owner of the dogg shall pay damage. If a man refuse to tye up his dogg's legg, and hee bee found scrapeing up fish in a cornfield, the owner thereof shall pay twelve pence damage beside whatever damage the dogg doth. But if any fish their house lotts and receive damage by doggs, the owners of those house lotts shall bear the damage themselves."

beef," opens up a vast field for future development. As a food for the domestic animals in the form of "fish meal," there seems also to be a broad opening. As a source of oil, the menhaden is of more importance than any other marine animal. Its annual yield usually exceeds that of the whale (from the American fisheries) by about 200,000 gallons, and in 1874 did not fall far short of the aggregate of all the whale, seal and cod oil made in America. In 1878 the menhaden oil and guano industry employed capital to the amount of $2,350,000, 3337 men, 64 steamers, 279 sailing vessels, and consumed 777,000,000 of fish: there were 56 factories, which produced 1,392,644 gallons of oil, valued at $450,000, and 55,154 tons of crude guano, valued at $600,000; this was a poor year. In 1874 the number of gallons produced was 3,373,000; in 1875, 2,681,000; in 1876, 2,992,000; in 1877, 2,427,000. In 1878 the total value of manufactured products was $1,050,000; in 1874 this was $1,809,000; in 1875, $1,582,000; in 1876, $1,671,000; in 1877, $1,608,000. It should be stated that in these reports only four-fifths of the whole number of factories are included. The refuse of the oil factories supplies a material of much value for manures. As a base for nitrogen it enters largely into the composition of most of the manufactured fertilizers. The amount of nitrogen derived from this source in 1875 was estimated to be equivalent to that contained in 60,000,000 pounds of Peruvian guano, the gold value of which would not have been far from $1,920,000. The yield of the menhaden fishery in pounds is probably triple that of any other carried on by the fishermen of the United States. In the value of its products it is surpassed only by three; the cod fishery, which in 1876 was estimated to be worth $4,826,000; the whale fishery, $2,850,000, and the mackerel fishery, $2,275,000. The value of the menhaden fishery for this year being $1,658,000.

In estimating the importance of the menhaden to the United States, it should be borne in mind that its absence from our waters would probably reduce all our other sea-fisheries to at least one-fourth their present extent.

On the Species of Bornean Orangs, with Notes on Their Habits. By Wm. T. Hornaday, of Rochester, N. Y.

A comparison of the mammalian fauna of Borneo with that of the adjacent islands of the Malay archipelago and the Peninsula affords a most interesting and instructive study. This great equatorial island is the second largest in the world, and with an area of 280,000 square miles is equal to all the Eastern and Middle States with Maryland. It is distant in a direct line from the mainland of Asia 285 miles, from Sumatra the same distance, and from Java about 150 miles, yet the mammalian faunas of these several localities are as nearly identical as we have any reason to suppose they would be even if that whole region now formed one unbroken continent like Australia. If Hindostan could to-day be divided up into three great islands and a peninsula, it is almost certain that each locality would possess as many species peculiar to itself, and as many identical with those of the other three localities as do Borneo, Java, Sumatra, and the Malay Peninsula. According to Wallace, Borneo possesses, of terrestrial mammals sixty-two species, Java fifty-five, Sumatra sixty-six, and Malacca sixty-five, but with all this richness Borneo possesses but sixteen peculiar species, Java and Malacca only six each, and Sumatra only five. In short, the entire fauna of each so strongly resembles that of all the others as to force upon us the belief that at some former period these islands were all directly connected with the mainland of Asia, and formed another vast peninsula similar to Hindostan at the present day. Not only this, but when we note the slight degree of variation or else absolute identity of the species which are common to two or more of these localities, we are further led to believe that their final separation from the mainland and from each other must have occurred at a comparatively recent geological period.[1]

On the other hand, Celebes, which is separated from Borneo by Macassar Strait which is only seventy miles wide at Cape Kaniongan, possesses only sixteen species of terrestrial mammals all told, of which thirteen are probably peculiar to the island, and the remaining three only belong to the true Malayan fauna.

In fact, Borneo seems to be the last and most important link of a great, unbroken chain of mammals which reaches down from

[1] Wallace.

Europe, along southern Asia, through India and Ceylon, Burmah and Malayana to Borneo, where it is abruptly broken off. On the islands to the eastward of Borneo, beginning with Celebes, the Quadrumana, Insectivora, Carnivora, and Ungulata diminish rapidly until they disappear altogether. From northwestern Hindostan the mammalia seem to rise in the scale of organization until at this end of the chain we find a marked and peculiar richness in species of Quadrumana, Cheiroptera and Insectivora, especially the former.

This increasing richness of important forms is most noticeable in the Quadrumana. In northwestern Hindostan we find only the common species of *Presbytis* and *Macacus*, but in eastern Bengal occurs the *Nycticebus*, or slow-paced lemur, and in Ceylon and Madras the *Loris gracilis*. In Burmah we find the *Hylobates*, or gibbon, and at Malacca and in Sumatra we find not only another species of Hylobates, but also the *Siamanga syndactyla*, connecting link between the gibbons and the orang-utans. In northern Sumatra we find our first specimen of the huge, man-like *Simia satyrus*. But here its range is very limited, its occurrence rare, and it is not until we reach Borneo that we find the orang-utan in greatest numbers and attaining the largest size. Borneo is indeed the land of apes and monkeys. It contains thirteen species of Quadrumana, including the orang-utan (two species) the gibbon, the slow-paced lemur, the wonderful proboscis monkey (*Nasalis larvatus*, peculiar to the island), the *Tarsius spectrum* and *Galiopithecus*, or flying lemur.

For insular land Borneo is extraordinarily rich in large and important mammals, and we know not what may still be furnished by that *terra incognita* of its northeast quarter, and the whole interior, which, like New Guinea, is beckoning to naturalists with offers of unknown forms.

We now turn to a brief consideration of the group of anthropoid apes. Leaving the genus Homo out of the question, the orang-utan occupies the third place from the highest in the animal kingdom. The gorilla (*Troglodites gorilla*) is given the highest place, next in order is the chimpanzee (*T. niger*), after which comes the orang-utan (*Simia Wurmbii* and *satyrus*), followed by the *Siamanga syndactila*, the link between the orangs and the gibbons (*Hylobates*). The orang well deserves the place it

occupies. It agrees with the gorilla and chimpanzee in positive size and quality of the brain, but its fore-limbs as compared with the hind ones are longer than theirs, while they are also proportionally shorter than those of the *Siamanga* and *Hylobates*. The heel-bone (calcaneum) is proportionally longer in *Simia* than in *Hylobates*, and thus the orang is more capable of assuming an erect posture. Its thumb is also better developed than that of the gibbons. Among the higher apes the orang comes nearest to man in the number of ribs (twelve pairs) and form of the cerebral hemispheres, but differs from him in other respects, especially in the limbs, more than do the gorilla and chimpanzee.

The chimpanzee approaches man most closely in the character of its cranium, dentition and proportional size of its arms. The gorilla is more man-like in the proportion of the leg to the body, size of the heel, curvature of the spine, form of pelvis and absolute capacity of the cranium. In its habits the orang resembles the gorilla and chimpanzee which are not gregarious, while the gibbons are.

The most striking feature of the orang is its great size and general resemblance to man. The chest, arms and hands are especially human-like in their size and general outline. Since the animal depends mainly upon these members for the means of locomotion they are necessarily of massive proportions. The natural position of the human hand at rest is with the fingers slightly bent upward at the tips, but that of the orang is with the fingers fairly clenched, and when measuring our dead specimens, we often found it an absolute impossibility to straighten even a single finger without cutting the tendon in the palm of the hand. Thus when an orang is asleep it is the most natural position he can assume to be firmly grasping a branch with each hand.

Male individuals of the *Simia Wurmbii* are distinguished by their wonderful cheek callosities, each side of the face being greatly expanded and flattened into a thick, semicircular disk extending vertically from the top of the forehead to the angle of the jaw. This remarkable feature is a purely sexual characteristic, for it is never possessed by the female orangs. So far as I have been able to determine, these facial callosities are purely ornamental, since they are not controlled by voluntary muscles, and are composed merely of tough, white, semi-cartilaginous tissue such

as is found in the palm of the human hand. In different individuals these callosities vary in width from ten to thirteen and one-half inches.

The body color of orangs varies greatly in individuals, so that no importance can be attached to it in the determination of species. As a rule, all young orangs and nearly all females have a dark brown skin with palms of a still darker brown, or black in some old females, while nearly all large males, especially all of the *Simia Wurmbii* have black skins with the more hairless portions of the face and hands and all their palms of a deep, shiny black very slightly tinged with brown. The faces and palms of infant orangs are usually a light brown, sometimes amounting to yellowish brown.

The eyes of adults are always very small indeed, with iris of a dark chestnut brown and no white visible. The teeth are invariably very much discolored by vegetable acids and juices, and the base of each tooth is always black.

The hair of an orang is usually of a brick red, varying to dark red, and sometimes so light a brown as to be almost strawcolor. Sometimes the hair is abundant, coarse and ten to fifteen inches in length, and in other specimens it will be scanty, short and much finer. The throat is never really clothed with hair.

On most of the *Simia Wurmbii* there seems to be a superabundance of skin on the throat and breast, for it is often found to hang in a great baggy fold of loose skin. Externally, the orang seems to have no neck at all, the head being set squarely down upon the shoulders. The chest is massive to correspond with the arms and head, but the pelvis is small, and the lower limbs are small, short and comparatively weak. The orang never sits down as do the gibbons and therefore it has no ischial callosities like the Hylobates.

There is no *ligamentum teres* in the orang, and the absence of this permits of great freedom of movement in the lower limbs. Indeed the legs seem to possess almost as much freedom of movement as the arms. I have often seen my little pet orang hang to a rope with one arm at an angle of fully 70° and with the greatest comfort imaginable reach up with his leg at the very same angle and grasp the rope with his foot.

Some authors, Dr. Cantor among the number, attach some importance to the facial resemblances of different orangs. I have

never seen living specimens of the Sumatran orang, but so far as Bornean species are concerned I am certain that each individual differs as widely from his fellows and has as many facial peculiarites belonging to himself as can be found in the individuals of any unmixed race of human beings. According to my experience, orangs differ from each other fully as much as do either Chinese or Japanese, if not more.

The faces of the more intelligent orangs are capable of a great variety of expression, and in some the exhibition of the various passions which are popularly supposed to belong to human beings alone is truly remarkable. I had in my possession in Borneo four young living orangs. Three were dull and untractable, but the fourth was a perpetual wonder to both Europeans and the natives themselves. I had that little animal in my possession for over four months, and for a number of weeks it lived in the room with me so that I watched it almost constantly. The expression of its face was highly intelligent, while the intellectual development of its forehead and entire cranium would have been quite alarming to any enemy of the theory of evolution. This specimen was a fine, healthy male infant from 7 to 8 months old, height 22¼ inches, extent of arms 37 inches, weight 15½ lbs. He exhibited fully as much intelligence as any child under two years of age, with all the emotions of affection, dislike, anger, fear, cunning, playfulness and even ennui. When teased beyond endurance he would first whine pitifully, but if continued he would throw himself upon the floor, kicking and screaming and catching his breath as loudly and naturally as any spoiled child. He was afraid of strangers as a rule, but decidedly attached to my Chinese servant and myself. When alarmed at the presence of a large dog or other animal he would shuffle up to me as fast as possible and climb with all haste into my arms. While the statement may seem frivolous in this connection, it is really a serious fact that, whenever a cat happened to come near him, he would immediately grab it by the tail with the very same action and bright mischievous expression of countenance as we have all seen in human children.

Male orangs are much given to fighting, as the numerous scars upon some of our specimens plainly show. Being purely fruit-eating animals their huge canine teeth seem to have been given them partly as weapons of defence and offence, and they use them to decided advantage. Like many roughs of the human species

they seem given to attacking each other's fingers with their teeth, since their jaws do not open sufficiently wide to seize an arm or shoulder to good advantage. Some individuals are very pugnacious or else sorely persecuted. Orang No. 11, *Simia Wurmbii*, carried the scars of many a hard-fought battle in the treetops. A piece had been bitten out of the middle of both upper and lower lip leaving a great ragged notch in each, and both his middle fingers had been bitten off at the second joint. Not only that, but on the feet, the third right toe had been bitten off, as well as the fourth left toe and the end of the hallux. This specimen we named "The Desperado."

Orang No. 34, male *Wurmbii*, had almost lost the edge of his entire upper lip. It had been bitten diagonally across, but still adhered at the left corner, and the wound had evidently healed very quickly, for that triangular piece of his upper lip still hung dangling two inches down from the corner of his mouth. He had also lost an entire finger.

No. 36 had lost a piece out of his upper lip, and his left first toe had been bitten quite off.

Whenever my baby orang became angry with me he would if possible seize me by the wrist and draw my hand up to his mouth until he could seize one of my fingers with his teeth; but, while he would make a great feint of giving me a terrible bite, he knew enough not to bite harder than I could comfortably endure. It is the natural instinct of an orang to seize and bring the offending hand of another to its mouth instead of moving its heavy head and body to the object. Thus in every imaginable way do the powerful and capable limbs and hands serve the heavy, inert body and head upon all occasions.

The genus *Simia* occurs in northern Sumatra, but its distribution in Borneo is so much more extensive that we may well say Borneo is the home of the orang-utan. There it inhabits that wide belt of low, forest-covered swamps which lies between the seacoast and the mountain ranges of the interior, extending entirely round the western half of the island. But even this great alluvial plain is inhabited by the orang in certain districts only, although all those portions which are covered by lofty virgin forests *seem* to present the same features. In the Territory of Sarawak, the orang, or "mias" as it is called by the natives, is found along the rivers Batang Lupar and Sadong and their small tributaries such

as the Liugga and Simujan. It does not occur at all along the the Sarawak or Samarahan rivers, but farther west it is found, though more rarely, from the river Sambas to the Kapuas, which latter lies directly under the equator. It is also found in certain districts along the south coast of Borneo, although its limits there do not seem to be very clearly defined.

Last year while on a collecting expedition to the East Indies for Prof. H. A. Ward, I was afforded ample opportunities for studying the habits of the orang-utan in its native forests. I visited Borneo in the month of August, 1878, for the sole purpose of obtaining specimens of the Bornean *Simia*, and to study the different species from fresh specimens.

I visited the Territory of Sarawak, and for two and a half months devoted my entire time and attention to hunting the orang along the river Sadong, and its tributary the Simujan. This whole region is one vast swamp, in some places entirely inundated at that season, covered everywhere with a dense growth of virgin forest. Isolated hills or mountains rise here and there like islands out of a sea, to a height of 600 to 1000 feet, clothed to their very summits with heavy forest. Upon these hills grow many noble fruit trees, and in the fruit season the orang-utans from the surrounding swamps repair to them for their yearly feast. Unfortunately I arrived in the orang country long after the regular fruit season, and not a single individual could I find upon any of the hills. After diligent inquiry amongst the Malays and Dyaks we learned that our only chance of finding orangs was to hunt along the rivers. The natives asserted that at that season many of the orangs were attacked by fever, which led them to visit the river sides to get the benefit of the cool breezes generally blowing there. Certain it is that while we hunted far and wide we never, save upon two occasions, found any orangs elsewhere than close to some river or lake margin. Along the head waters of the Simujan this was accounted for by the fact that they were feeding upon the young shoots of a species of Pandanus or screw pine which we found growing in the water everywhere above the influence of the tide.

During the fruit season, which is from the middle of January to the first of May, the food of the orang is the durion, mangosteen and rambutan which are usually found upon the hills. There are also other fruits which ripen at different times, such as the ráso and

kapayáng, but of the former the orangs eat the shoots only. Besides these they devour the shoots of the Pandanus, and also the leaves of certain trees. During the hot months of May, June and July, they retire far into the depths of the forest and are exceedingly difficult to find, but during the season of the heaviest rains, *i. e.*, from August to November, when the forests are quite flooded, the orangs are found in the vicinity of the rivers.

I soon found that the only way to reach them would be to paddle up and down the rivers and watch for them in the treetops. Accordingly I procured a small Malay "sampan" and two Malays to paddle it, and our first venture was up the Simujan river to Padang lake at its source. Above the influence of the tide we found the forest for two or three miles on both sides of the river completely flooded with water to a depth of two to five feet, and had it not been for the underbrush we could have paddled about through the forest with the greatest ease. Near the source of the Simujan river and far beyond the last Dyak village we found great numbers of old orang or "mias" nests, and some which were quite new.

The nest of the orang-utan consists of a quantity of leafy branches broken off and piled loosely into the fork of a tree. He usually selects a small tree, a sapling in fact, and builds his nest in its top, even though his weight causes it to sway alarmingly. He always builds his nest low down, often within twenty-five feet of the ground, and seldom higher than forty feet. Sometimes it is fully three feet in diameter, but usually not more than two, and quite flat on the top. There is no weaving together of branches, for they are merely piled crosswise as a natural consequence of their being broken off on different sides of the nest. In short, the orang builds a nest precisely as a man would build one for himself were he obliged to pass a night in a treetop and had neither axe nor knife to cut branches. I have seen one or two such nests of *men* in the forest where the builder had only his bare hands with which to work, and they were just as rudely constructed, of just such materials and in about the same general position, as the average orang nest. Upon this leafy platform the orang lies prone upon his back with his long arms and short, thick legs thrust outward and upward, firmly grasping while he sleeps the nearest large branches within his reach. On several occasions I surprised

individuals upon their nests, and once I had an opportunity to watch an orang while it constructed its resting-place.

During one day's travel along the Upper Simujan river we counted thirty-six old nests and six which we set down as new, or fresh. I have never been able to ascertain to a certainty, but it is my opinion that an orang after building a nest sleeps in it several nights in succession, unless he is called upon to leave its neighborhood altogether. Certain it is that whenever a hunter finds a perfectly fresh nest he may with confidence expect to find the builder somewhere near it. An orang never uses a nest after the leaves become withered and dry, no doubt for the reason that the bare branches afford an uncomfortable resting-place. I never saw nor heard of any house-building by orang-outangs, though I am led to believe that some individuals may have a habit of covering their bodies with branches for protection against the dashing of the rain-drops during a heavy storm. My little pet orang would invariably cover his head and body with straw or loose clothing the moment it began to rain, even though he was under a roof all the time.

We found the orangs most numerous along the Simujan river near its source. Our manner of hunting was to make trips up and down the river in our boat, paddling slowly and silently along, keeping a bright lookout and carefully examining every doubtful object with the field-glass. Sometimes, in rounding a bend in the river, we would come full upon a huge, black-faced, red-haired animal reposing quietly, or comfortably feeding, and sometimes our attention would be attracted merely by the swaying of a small treetop fifty yards inland. If the treetop swayed slowly, and bodily, we knew it was not done by any but a slow-moving, heavy-bodied animal, and the attack would be begun at once.

On sighting an orang, the Malays would stop the boat as quickly as possible, and, rising in my place I would fire at him with my small-bore rifle, aiming to shoot him through the chest, and thus either kill him at once or disable him so that he would be unable to get far away. The trees in which we usually found orangs were quite low, thinly leaved and far apart, so that on several occasions I succeeded in killing a large specimen with a single bullet. It would, at all times, have been an easy matter to have shot them through their heads, but this would have ruined their skulls.

As soon as an orang was fired at, if not killed outright, he would begin climbing away with all haste. Being armed with a breech-loader I could generally fire one or two snap shots at him as he ran, before he would be hidden from view. Then the boatmen would drive the boat into the thick fringe of screw pines (*Pandanus*) which always bordered both sides of the river, and with feverish haste their long, supple stems would be thrust aside and cut away until we had forced a passage for the boat, and reached the more open vicinity of the large trees where wading became possible. Keeping a careful eye upon the direction taken by our orang, we would drop overboard, holding the rifle and cartridge-bag above our heads, and begin wading toward our intended victim. Usually we would be waist deep in the water, often it came up to our necks, and once we went under entirely and had to swim a short distance. Being unemcumbered it was the special business of the boatmen to push ahead with all speed, find the orang, and keep him in view until I could come up with my rifle.

In such an unequal race as that, an unwounded orang would have invariably escaped us. Our progress through the water would often be terribly impeded by submerged logs and trailing vines and creepers, but we were always successful in coming up with our wounded orang, generally to find him almost disabled and greatly weakened from loss of blood. Once found, one or two careful shots would be sufficient to send him tumbling and crashing down through the branches to fall into the water with a tremendous splash.

Even under the most favorable circumstances, orangs are neither graceful nor active in their movements. I think we may fairly consider them the most helpless of all the Quadrumana. Owing to the great weight of their bodies, and the peculiar structure of their hands they cannot run nimbly along even the largest branches, and never dare to spring from one tree to the next. The smaller monkeys go galloping madly along the larger branches, with outspread arms, legs and tail leap recklessly from the tree-top, go flying through the air for several yards, and fall sprawling and unhurt upon the side or in the leafy top of the next tree. Not so the orang-outang, with his huge, flabby stomach, fleshy thighs and massive head. His weight of one hundred and twenty to sixty pounds compels him to move slowly and circumspectly so that he may not find himself falling heavily to the ground. Owing

to the disproportionate shortness of his legs, his progress depends mostly upon his long, sinewy arms, and very often he goes swinging through a treetop by their aid alone. Often I have seen them swing along the under side of a large limb as a gymnast swings along a tight rope, reaching six feet at a stretch. When passing from one tree to another he reaches out and gathers in his grasp a number of small branches that he feels sure will sustain his weight, then swings himself across.

Upon the ground the orang is a picture of abject helplessness. In their native forests they are very seldom known to descend to the earth, and so far as my experience goes I have never seen nor heard of a single instance of the kind. True, they climb down when thirsty until they can reach the water with their hands, but this occurs where there is no dry land to walk upon.

The orang-utan is utterly incapable of standing fully erect without touching the ground with its hands. I have seen many orangs in captivity, but not one of them ever stood erect upon its hind legs for a single instant, and for orangs to be so represented in drawings or museums is contrary to nature.

There has been considerable discussion in regard to the maximum size attained by the orang-utan, and its general measurements. Mr. A. R. Wallace, in his work on the "Malay Archipelago," pp. 72, *et seq.*, makes the following statements:

"I have myself examined the bodies of seventeen freshly-killed orangs. * * Of this extensive series sixteen were fully adult, nine being males and seven females. The adult males of the large orangs only varied from 4 ft. 1 in. to 4 ft. 2 in. in height, measured fairly to the heel, so as to give the height of the animal if it stood perfectly erect; the extent of the outstretched arms from 7 ft. 2 in. to 7 ft. 8 in.; and the width of the face from 10 in. to 13½ in. The dimensions of other naturalists closely agree with mine. The largest orang measured by Temminck was four feet high. Of twenty-five specimens collected by Schlegel & Müller, the largest old male was 4 ft. 1 in., and the largest skeleton in the Calcutta Museum was, according to Blyth, 4 ft. 1½ in.: * * * * and no specimen has yet reached Europe exceeding these dimensions, although the total number must amount to over a hundred. * * * On the whole, therefore," concludes Mr. Wallace, "I think it will be allowed that up to this time we have not the least reliable evidence of the existence of orangs in Borneo more than 4 ft. 2 in. high."

The total number of specimens of the orang-utan of both species killed by myself and my hunters was forty-three, every one of which I carefully measured while fresh and recorded each measurement the moment it was made. I saved the skin of every one of these specimens, and the skeletons of all save three or four of the very youngest ones. Of this large number only fourteen males were fully adult, *i. e.*, had reached a state of perfect maturity as shown unmistakably by the disappearance of the frontal and parietal sutures, and the worn condition of the teeth. Of the females I shall *consider* only four as fully adult, which fact is fully proven by their skulls, and partly by the presence of their young. The other females I propose to leave out of consideration at this point. I shall lay special stress upon the measurements of these eighteen adult specimens, for I consider this the key to the puzzling question of species.

In the first place, no fewer than seven of my specimens exceeded the maximum height for orangs as given by Mr. Wallace, viz., 4 ft. 2 in., even by the most liberal measurement. My largest *Simia Wurmbii*, called "Mias chappin" by the natives, measured 4 ft. 6 in. from head to heel, and the next in size 4 ft. $5\frac{1}{2}$ in. Then a *Simia satyrus*, or "Mias rombi," measured 4 ft. $4\frac{1}{2}$ in., two other *Wurmbii* 4 ft. 4 in. and 4 ft. 3 in. respectively, a *satyrus* 4 ft. 3 in. and a *Wurmbii* 4 ft. $2\frac{1}{2}$ in. Only one specimen measured exactly 4 ft. 2 in., and the remaining nine fell below that height. One male specimen, with hair which grew to a length of 12 to 15 in. in some places, measures only 3 ft. $10\frac{1}{4}$ in. in height. The largest female measured only 4 ft. and the smallest *adult* female 3 ft. 6 in. These measurements were a great surprise to me, and feeling sure that sooner or later their accuracy would be called in question, I made and recorded them with unusual care and exactness. To obtain the height it was my practice to lay the animal upon its back, with the legs held straight by an assistant, then holding the blade of a large knife flat against the top of the head, the blade was thrust perpendicularly down into the table or the earth. Then while an assistant held the top of the head against the first knife-blade, I pressed another blade firmly against the bottom of the heel and thrust it into the earth also. After moving the animal aside a tape line stretched between the inner surfaces of the knife blades gave the height of the animal to within a small fraction of an inch. Not a

single figure was ever trusted to my memory alone, and my largest orangs were each measured and recorded twice.

From the subjoined table of measurements of the eighteen adult orangs we glean a number of important facts which bear directly upon the question of species:

SIMIA WURMBII,—"MIAS CHAPPIN."		SIMIA SATYRUS,—"MIAS ROMBI."		
Height.	*Spread of arms.*	*Height.*	*Extent of arms.*	
No. 18. ♂. 4 ft. 6 in.	7 ft. 11½ in.	No. 9. ♂. 4 ft. 4½ in.	8 ft. 0 in.	
No. 13. ♂. 4 " 5½ "	7 " 10¾ "	No. 38. ♂. 4 " 3 "	7 " 4 "	
No. 43. ♂. 4 " 4 "	7 " 4½ "	No. 6. ♀. 4 " 0 "	7 " 3¾ "	With Young.
No. 25. ♂. 4 " 3 "	7 " 6 "	No. 35. ♀. 3 " 9½ "	6 " 7 "	
No. 8. ♂. 4 " 2½ "	7 " 4¼ "	*Called by the natives "MIAS KASSAR."*		
No. 21. ♂. 4 " 2 "	7 " 2 "	No. 37. ♀. 3 ft. 6 in.	6 ft. 2½ in.	
No. 26. ♂. 4 " 1½ "	7 " ¾ "	No. 28. ♀. 3 " 8¾ "	6 " 2¼ "	
No. 34. ♂. 4 " ¾ "	7 " 4 "			
No. 30. ♂. 4 " ¾ "	7 " 2 "			
No. 29. ♂. 4 " 0 "	6 " 11½ "			
No. 36. ♂. 4 " 0 "	7 " ½ "			
No. 11. ♂. 3 " 10¼ "	6 " 9 "			

First. Of the twelve specimens which we know by their facial callosities and single cranial ridge to be *Simia Wurmbii*, all are males, which justifies the belief that the females of that species have neither the callosities nor the elevated cranial ridge.

Second. Of the four females which we know by the disappearance of their frontal and parietal sutures and the worn condition of their teeth to be fully adult, not one reaches the average height of adult males (4 ft. 2 in.), and only one female reaches the height of 4 ft., the other three but slightly exceeding 3½ ft.

Third. Out of eighteen orangs of all species and all known to be fully adult, fourteen are males and only four females. But

Fourth. Of the remaining twenty-five orangs (in our collection of forty-three), seventeen are females and only eight males.

Fifth. Of these seventeen females, thirteen are of such uniform size that their variation in height is all included between 3 ft. 3½ in. and 3 ft. 9 in. Hence we have every right to class these

thirteen females as belonging to the same period of orang life, and to believe that a certain proportion of the number must be adult. Taking all the above facts into consideration, we reach the inevitable conclusion that in all species of the Bornean orang the average adult female is very much smaller than the average adult male.

Sixth. In our series of forty-three orangs, we find the sexes equally represented by twenty-two males and twenty-one females; and while we find well-marked external differences between the males of the two species, there are positively no well-marked external specific differences between the females of *Simia Wurmbii* and *satyrus*, such differences as do exist being very slight and purely structural.

Seventh. As may be plainly seen from the foregoing table of measurements, adult orangs vary fully as much in their various proportions as do human beings. For example, the arms of No. 26, which stands 4 ft. 1½ in. high, are full three inches shorter than those of No. 6, which stand only 4 ft. No. 9 has a short body and legs with very long arms, while No. 38 has a long body and legs but short arms. The breadth of the facial callosities of the *Wurmbii* bears no relation whatever to the size of the animal. The largest orang of all, No. 18, measured only 11¼ in. across the face, while No. 25, which stood three inches shorter, and was much smaller every way, measured 13½ in. across the face.

According to my experience, the color, quality, quantity and texture of the hair have nothing whatever to do with the determination of species.

Orangs are liable to possess individual peculiarities to a greater extent than perhaps any other of the apes or monkeys. To illustrate: No. 26, *Simia Wurmbii*, with a very prominent cranial ridge was utterly destitute of facial callosities or any sign of them, and until dissection was supposed to be a *satyrus*. No. 13 has a nail on the hallux of its hinder hands. No. 21 has four molars in each side of its lower jaw while the other forty-two orangs have only three each. Such facts as the above illustrate the inadvisability of founding a species upon a few peculiarities observed in a single specimen as was the case with the creation of *Simia morio* by Prof. Owen.

It will be readily seen by an examination of our series of skulls

that orangs of both species vary exceedingly. For example, compare the narrowness of the interorbital space and the small facial angle of skull No. 39 with the broad interorbital space and unusually great facial angle of No. 35, both of which are *Simia satyrus*. Compare skull No. 11 with No. 43 and note how the orbits of the former are lengthened laterally, and of the latter vertically; the sharp temporal ridges of No. 43 which meet in front of the parietal suture and form a sharp and greatly elevated sagittal crest which is continued almost as far back as the lambdoidal crest, with the broad and rather depressed temporal ridges of No. 11 which converge regularly until they almost touch on the top of the cranium, and from thence immediately diverge to form the lambdoidal crests. In reality No. 11 has no proper sagittal crest at all, although the surface of the cranium is very rugose and the teeth greatly worn, indicating a much greater age than that of No. 43.

In the skull of No. 21 we find a still greater departure from the typical sagittal crest of the *S. Wurmbii*, as seen in No. 43. In No. 21 the temporal ridges are very prominent, but they are so widely separated throughout their entire length that even on the top of the cranium, where they are supposed to unite they are fully three-quarters of an inch apart, thus resembling, in a measure, the skull of the adult *Simia satyrus*. Indeed, if any one possessed this skull alone with no data concerning the living specimen, it would be a perfectly natural mistake to call this *Simia satyrus*, as described by even the best authors; but since we have before us three other specimens, Nos. 11, 34, and 43, which show how gradual is the variation in individuals of the same species from the single, elevated sagittal crest to the two cranial ridges which even at the top of the cranium are fully three-fourths of an inch apart, we see at a glance that No. 21 is *Simia Wurmbii* as surely as No. 43. We may add to this the fact that No. 21 was when living a male specimen with facial callosities measuring thirteen and one-half inches in width.

I believe that with a comparative series of skulls at hand it is an easy matter to refer any orang skull to one or the other of the two species *Simia Satyrus* and *Wurmbii*, and that too upon evidence which will be apparent to the most casual scientific observer. To the very last I have been quite unable to find in our

collection any specimen which could upon any reasonable grounds be referred to Prof. Owen's *Simia morio*. It is true that the existence of such a species of Bornean orang is virtually admitted by many naturalists, and also that the natives of Borneo are quite positive in their distinction of three kinds of mias, viz., mias chappin, rombi and kassar. Now one of the special characteristics of the skull which Prof. Owen describes as *Simia morio* (Proc. Zöol. Soc., 1836, p. 92) is the absence of either sagittal crest or cranial ridges on the top of the cranium, and yet he says (p. 93):

"There are, however, the rudiments of the ridges which so remarkably characterize the cranium of the mature Pongo. Those which commence at the external angle of the frontal bone pass backwards, upwards, and slightly converge, but do not meet; they gradually diminish in breadth, and after passing the coronal suture subside to the level of the skull; they are then only traceable by a rough line, which leading parallel to the sagittal suture, and gradually bending outwards, rise again to be continued into the lambdoidal ridges; thus circumscribing the origin of the temporal muscles."

In his table of measurements, Prof. Owen records the "distance between temporal ridges" as only seven lines, or a little more than half an inch.

Another distinctive characteristic of the *Simia morio* is its diminutive size, being generally considered one-third smaller than the adult males of the other two species. This would give it a height scarcely exceeding three feet. Strange to say however, we have no record, so far as I have been able to discover, of the existence of a single cranium or other specimen of the adult *male Simia morio*. This fact is full of significance when taken in connection with that of the very small size of nearly all female orangs.

Now we have three skulls of specimens which were called Mias kassar (*i. e.*, *Simia morio*) by the Bornean natives. No. 28 is the skull of an old female which was 3 ft. 8¾ in. high. A dissection of this specimen revealed a well-developed fœtus. The next skull, No. 17, is clearly a *satyrus*, and so very young as to be scarcely entitled to consideration. The other, No. 35, is of a very old female, which stood 3 ft. 9½ in. high.

Let us compare these with the other female skulls in our series.

No. 6 is of a female *Simia Wurmbii*, four feet high, but the temporal ridges, like those of Prof. Owen's specimen, "subside to the level of the skull soon after passing the coronal suture, and are then only traceable by a rough line." This description applies exactly to both 6 and 28, and it is plain to be seen that if the large one is *Simia Wurmbii*, which we know it to be, then the other is of that species also. In short, the two are identical.

No. 35, the other adult mias kassar, is clearly an *S. satyrus*, as is plainly indicated by the two rough temporal lines on the skull which correspond exactly to the two elevated ridges on the skull of the adult male. No female skull in our collection possesses either the two *continuous* temporal ridges or the sagittal crest, but every adult female skull exhibits the rough lines corresponding to the elevated ridges of the males, and clearly designate either the species *S. Wurmbii or satyrus* in every case. It is my impression that the skull described by Prof. Owen as *Simia morio* was simply a female Wurmbii (below the average size?) in which the temporal ridges did not quite meet, as is shown in skull No. 11, and still more strikingly in skull No. 21, where they do not approach each other even upon the top of the skull, nearer than full three-fourths of an inch.

Hence we see that our entire series of forty-three specimens furnishes not a single one which can be considered as belonging to any other than the two species *Simia Wurmbii* and *satyrus*, although it is a significant fact that these specimens were all collected in the very district which has furnished all the specimens of the so-called *S. morio*. While it is certainly possible that in making this large collection we could have failed to secure even a single specimen of a species existing in that locality, it is so highly improbable that I am convinced no third species exists there, neither any animal which could upon any tenable grounds be considered even a distinct variety of either of the two existing species.

We will not say anything about the part of orangs in the long chain of evolution, for we feel that no one present will wish to admit his or her relationship. But while abstract argument leads hither and thither according as this or that writer is most ably gifted for the same, there is still one argument or influence to which every true naturalist is amenable, and which no one will

ignore who has studied from nature any group of natural forms. Let such an one (if indeed such an one exist to-day) who is prejudiced against the Darwinian views go to the forests of Borneo. Let him there watch from day to day this strangely human form in all its various phases of existence. Let him see it climb, walk, build its nest, eat and drink and fight like human roughs. Let him see the female suckle her young and carry it astride her hip precisely as do the coolie women of Hindostan. Let him witness their human-like emotions of affection, satisfaction, pain and childish rage,—let him see all this and then he may feel how much more potent has been this lesson than all he has read in pages of abstract ratiocination.

PHILOSOPHY OF THE PUPATION OF BUTTERFLIES AND PARTICULARLY OF THE NYMPHALIDÆ. By CHARLES V. RILEY, of Washington, D. C.

[FULL ABSTRACT.]

THE comparatively sudden transitions from one state to another in insects have always excited the keenest interest. The change from larva to chrysalis in those butterflies known as *suspensi*, and

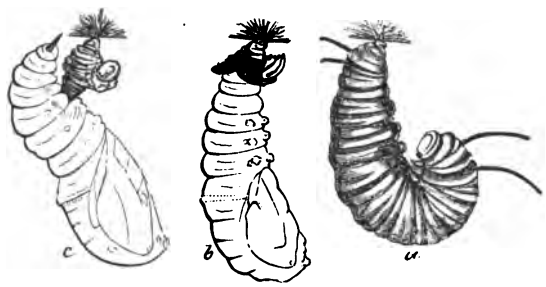


FIG. 1.—Ideal figures of *Danais archippus*, illustrating the method of pupation formerly accepted: *a*, suspended larva; *b*, forming chrysalis with shrivelled larva skin; *c*, method of holding skin during the last critical act. (After Riley.)

which in the chrysalis state hang from the tip of the body, has,

perhaps, been looked upon as the most wonderful. The preliminary acts in the performance have been pretty well observed and described by various authors since the days of Vallisneri, the larva hanging by the anal end, turning up the anterior part of the body in a more or less complete curve, and the skin finally splitting from the head to the front edge of the metathoracic joint and being worked back in a shrivelled mass toward the point of attachment. Now comes the critical feat which has most puzzled naturalists, viz., the independent attachment of the chrysalis and the withdrawal from and riddance of the larval skin which such attachment implies.

Réaumur explained it in 1734 by the clutching of the larval skin between alternate sutures of the soft joints of the chrysalis, and his happy and circumspect account, from observations made on *Vanessa urticæ*, has formed the basis for subsequent accounts; or, at least, no one obtained a deeper insight into the philosophy of the act until, some two years since, Dr. J. A. Osborne, of Milford, England, discovered that a distinct membrane is concerned in it. In casual observations of the process I had long become convinced that the popular accounts were crude and inaccurate, and had preserved specimens in the act of transforming for future study; but the philosophy of the change cannot be satisfactorily made out from alcoholic specimens alone, nor from the study of one species. The present paper is based on observations made on species in more than a dozen genera, the conclusions having been partially presented last June to the Philosophical Society of Washington.

The body of the larva is composed (exclusive of the head) of twelve segments or joints *and a subjoint*. It is with this subjoint that we have here to deal, for to it are appended the anal prolegs beneath, and the anal plate above the rectum.

If we carefully examine the anal plate of the larvæ of the true *suspensi*, we shall find that while it differs in form it has one feature in common, viz., the being furnished dorsally and posteriorly with numerous short spines and points, generally retrorse, or so placed that the larva can make use of them in suspending. These special spines on the anal plate are only fully developed after the last larval moult, being more or less obsolete in the earlier stages, and they are also under muscular control. Even in the *succincti*, where, as a rule, the anal plate is not specialized, spines are nevertheless sparsely found, especially on the hind border.

All writers that I have consulted speak of the larval suspension being due to the entanglement of the hooks of the anal prolegs in the silk, and do not mention the use of the anal plate, for which the hillock of silk is sometimes spun in special form.[1]

The normal form of this hillock may be likened to that of an inverted settee, or shoe, or to a ship knee, and one of the most interesting acts of the larva, preliminary to suspension, is the bending and working of the anal parts in order to fasten the back of the plate to the inside of the back of the settee, while the crotchets of the legs are entangled in the more flattened position or seat. In some cases (as in *Danais*), the hillock of silk is more elongate, and the spines of the truncate plate occur most around the lower margin, and even beneath it, so that in fastening them the larva seems to be drawing the silk up the rectum. In other cases (as in *Euptoieta*), the plate, in addition to the spines, has a prominent tubercle on each anterior outer border, well calculated to lock securely into the silk. After suspension, and as the fluids gravitate anteriorly, the silken hillock becomes more conical (the threads being loosely spun and elastic), and the hooks both of the plate and the prolegs hang more loosely from it.

In the final getting rid of the larval skin and attachment of the chrysalis there are concerned:

1st. Certain features belonging to the larva and cast off with its skin. 2d. Those belonging to the chrysalis; and to explain intelligibly the process it is necessary to characterize and homologize these parts more fully than has hitherto been done.

In the former category, in addition to the natural adhesiveness of the moist and mucous separating membrane, there are three physiological factors concerned: 1st. The *tracheal ligaments* (Fig. 2, *tl*), or the shed tracheæ from the last or ninth pair of spiracles, which uniformly become blind or obsolete in the chrysalis; 2d. The *rectal ligament* (Fig. 2, *rl*), or shed intestinal canal; 3d. The Osborne or retaining membrane (*membrana retinens*, Fig. 2, *mr*),

[1] It is an interesting fact in this connection that Rösel, who has never had any superior as a delineator of insect larvæ, makes the Nymphalids in his figures all suspend to an elongate, conical piece of silk, apparently issuing from the anus, with the legs invariably free and in no instance hooked. It is evident, however, from his text, that he was not aware of the use of the anal plate, and since he speaks of the larvæ attaching themselves by the hind legs or extremity, it is equally evident that his figures do not correspond with the text; while the freedom of the legs in his figures, is, of course, an error.

which is but a stretched part of the mucous membrane[2] that accumulates around the rectum and in the anal prolegs, and that is intimately connected with the rectal ligament.

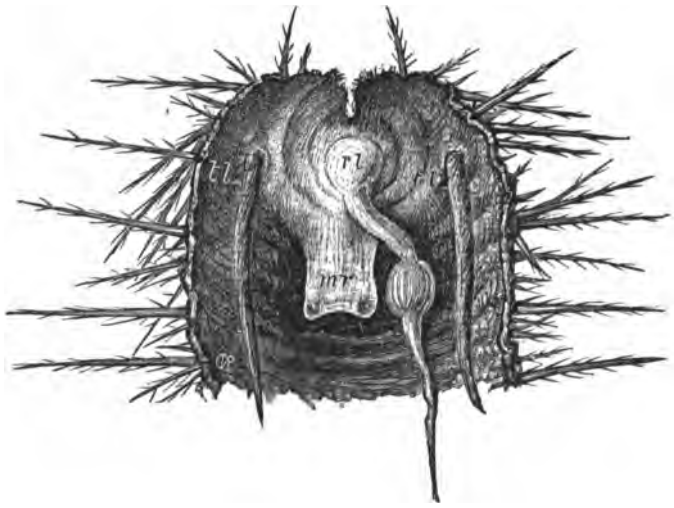


FIG. 2.—Shrunken larval skin of *Vanessa antiopa*, cut open from the back, and showing (*mr*) the retaining membrane, (*rl*) the rectal ligament, and (*tl*) the tracheal ligaments. (After Riley.)

In the second category we have the structural features of the chrysalis. (See Figs. 3, 4, 5, where corresponding parts are similarly lettered.) These are:

First. The *cremaster* proper (*c*), which is the homologue of the anal plate of the larva, and the form of which is foreshadowed in that of said anal plate. This cremaster assumes a great variety of different forms, but in general may be said to be a tapering piece, more or less incurved ventrally, and having the ventral and dorsal margins thickened or ridged, and these ridges may be respectively called the *ventral* and the *dorsal cremastral ridges* (*vcr* and *dcr*). This cremaster is surmounted at the apex and sometimes along the ventral ridges by what may be called the *cremastral*

[2] I designate by this name the colorless lining of the larval skin that separates from the forming chrysalis. If, as recent physiological research indicates, it is only the outer half of the outer or epidermic layer of the skin (*cuticula* of modern histologists) which is cast off in the exuviation of invertebrates, then this mucous lining is developed between the two separating layers of said *cuticula*.

hook-pad (*chp*), thickly studded with minute but stout hooks, which are sometimes compound or furnished with barbs, very much as are some of our fishing hooks, and which are most admirably adapted to the purpose for which they are intended.

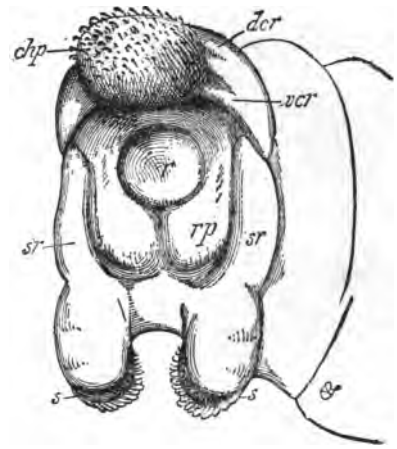


FIG. 3.—Ideal representation of the anal subjoint of *Vanessa antiopa*, from behind, with the spines removed and all the parts forced apart by pressure so as to show the homologies of the parts in the chrysalis which are concerned in pupation; homologies indicated by corresponding letters in Fig. 4, except that *r* (the rectum) corresponds with *pr* in Fig. 4. (After Riley.)

Secondly. We have the sustainers (*sustentores*), two projections which homologize with the soles (*plantæ*) of the anal prolegs; and which take on various forms (*s*), but are always directed forward so as easily to catch hold of the retaining membrane. In the yellow butterflies (as *Calydrias*, *Terias*, *Colias*), where the body of the chrysalis is so thrown back that mere projecting tubercles would not suffice, we find them transformed into actual hooks (Fig. 5, *s* and *E*); while in some of the *succincti* they are little more than a thickening of the anterior margin of the subjoint. In all Lepidopterous pupæ these remnants of the anal prolegs are more or less indicated, while in certain moths (*Pterophoridæ*), where the pupa is partly suspended as it is in the *Nymphalidæ*, they are covered with long hooks similar to those at the tip of the cremaster and to those which, in the larva, armed the hind plantæ.

Thirdly. We have what may be called the *sustentor ridges* (*sr*), usually connected with the sustainers, and embracing them on the

perhaps, been looked upon as the most wonderful. The preliminary acts in the performance have been pretty well observed and described by various authors since the days of Vallisneri, the larva hanging by the anal end, turning up the anterior part of the body in a more or less complete curve, and the skin finally splitting from the head to the front edge of the metathoracic joint and being worked back in a shrivelled mass toward the point of attachment. Now comes the critical feat which has most puzzled naturalists, viz., the independent attachment of the chrysalis and the withdrawal from and riddance of the larval skin which such attachment implies.

Réaumur explained it in 1734 by the clutching of the larval skin between alternate sutures of the soft joints of the chrysalis, and his happy and circumspect account, from observations made on *Vanessa urticæ*, has formed the basis for subsequent accounts; or, at least, no one obtained a deeper insight into the philosophy of the act until, some two years since, Dr. J. A. Osborne, of Milford, England, discovered that a distinct membrane is concerned in it. In casual observations of the process I had long become convinced that the popular accounts were crude and inaccurate, and had preserved specimens in the act of transforming for future study; but the philosophy of the change cannot be satisfactorily made out from alcoholic specimens alone, nor from the study of one species. The present paper is based on observations made on species in more than a dozen genera, the conclusions having been partially presented last June to the Philosophical Society of Washington.

The body of the larva is composed (exclusive of the head) of twelve segments or joints *and a subjoint*. It is with this subjoint that we have here to deal, for to it are appended the anal prolegs beneath, and the anal plate above the rectum.

If we carefully examine the anal plate of the larvæ of the true *suspensi*, we shall find that while it differs in form it has one feature in common, viz., the being furnished dorsally and posteriorly with numerous short spines and points, generally retrorse, or so placed that the larva can make use of them in suspending. These special spines on the anal plate are only fully developed after the last larval moult, being more or less obsolete in the earlier stages, and they are also under muscular control. Even in the *succincti*, where, as a rule, the anal plate is not specialized, spines are nevertheless sparsely found, especially on the hind border.

All writers that I have consulted speak of the larval suspension being due to the entanglement of the hooks of the anal prolegs in the silk, and do not mention the use of the anal plate, for which the hillock of silk is sometimes spun in special form.[1]

The normal form of this hillock may be likened to that of an inverted settee, or shoe, or to a ship knee, and one of the most interesting acts of the larva, preliminary to suspension, is the bending and working of the anal parts in order to fasten the back of the plate to the inside of the back of the settee, while the crotchets of the legs are entangled in the more flattened position or seat. In some cases (as in *Danais*), the hillock of silk is more elongate, and the spines of the truncate plate occur most around the lower margin, and even beneath it, so that in fastening them the larva seems to be drawing the silk up the rectum. In other cases (as in *Euptoieta*), the plate, in addition to the spines, has a prominent tubercle on each anterior outer border, well calculated to lock securely into the silk. After suspension, and as the fluids gravitate anteriorly, the silken hillock becomes more conical (the threads being loosely spun and elastic), and the hooks both of the plate and the prolegs hang more loosely from it.

In the final getting rid of the larval skin and attachment of the chrysalis there are concerned:

1st. Certain features belonging to the larva and cast off with its skin. 2d. Those belonging to the chrysalis; and to explain intelligibly the process it is necessary to characterize and homologize these parts more fully than has hitherto been done.

In the former category, in addition to the natural adhesiveness of the moist and mucous separating membrane, there are three physiological factors concerned: 1st. The *tracheal ligaments* (Fig. 2, *tl*), or the shed tracheæ from the last or ninth pair of spiracles, which uniformly become blind or obsolete in the chrysalis; 2d. The *rectal ligament* (Fig. 2, *rl*), or shed intestinal canal; 3d. The Osborne or retaining membrane (*membrana retinens*, Fig. 2, *mr*),

[1] It is an interesting fact in this connection that Rösel, who has never had any superior as a delineator of insect larvæ, makes the Nymphalids in his figures all suspend to an elongate, conical piece of silk, apparently issuing from the anus, with the legs invariably free and in no instance hooked. It is evident, however, from his text, that he was not aware of the use of the anal plate, and since he speaks of the larvæ attaching themselves by the hind legs or extremity, it is equally evident that his figures do not correspond with the text; while the freedom of the legs in his figures, is, of course, an error.

which is but a stretched part of the mucous membrane[2] that accumulates around the rectum and in the anal prolegs, and that is intimately connected with the rectal ligament.

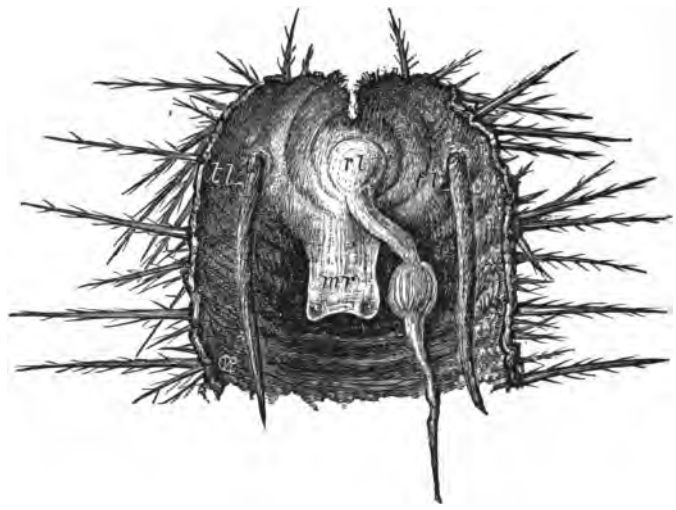


FIG. 2.—Shrunken larval skin of *Vanessa antiopa*, cut open from the back, and showing (*mr*) the retaining membrane, (*rl*) the rectal ligament, and (*tl*) the tracheal ligaments. (After Riley.)

In the second category we have the structural features of the chrysalis. (See Figs. 3, 4, 5, where corresponding parts are similarly lettered.) These are:

First. The *cremaster* proper (*c*), which is the homologue of the anal plate of the larva, and the form of which is foreshadowed in that of said anal plate. This cremaster assumes a great variety of different forms, but in general may be said to be a tapering piece, more or less incurved ventrally, and having the ventral and dorsal margins thickened or ridged, and these ridges may be respectively called the *ventral* and the *dorsal cremastral ridges* (*vcr* and *dcr*). This cremaster is surmounted at the apex and sometimes along the ventral ridges by what may be called the *cremastral*

[2] I designate by this name the colorless lining of the larval skin that separates from the forming chrysalis. If, as recent physiological research indicates, it is only the outer half of the outer or epidermic layer of the skin (*cuticula* of modern histologists) which is cast off in the exuviation of invertebrates, then this mucous lining is developed between the two separating layers of said *cuticula*.

hook-pad (*chp*), thickly studded with minute but stout hooks, which are sometimes compound or furnished with barbs, very much as are some of our fishing hooks, and which are most admirably adapted to the purpose for which they are intended.

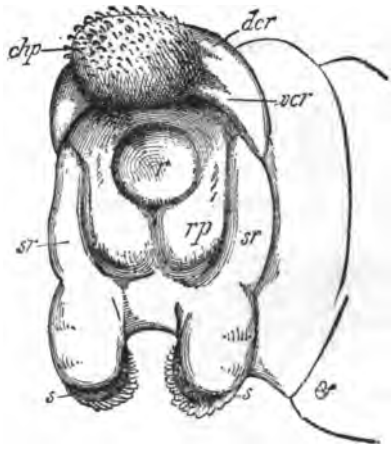


FIG. 3.—Ideal representation of the anal subjoint of *Vanessa antiopa*, from behind, with the spines removed and all the parts forced apart by pressure so as to show the homologies of the parts in the chrysalis which are concerned in pupation; homologies indicated by corresponding letters in Fig. 4, except that *r* (the rectum) corresponds with *pr* in Fig. 4. (After Riley.)

Secondly. We have the sustainers (*sustentores*), two projections which homologize with the soles (*plantæ*) of the anal prolegs; and which take on various forms (*s*), but are always directed forward so as easily to catch hold of the retaining membrane. In the yellow butterflies (as *Calydrias*, *Terias*, *Colias*), where the body of the chrysalis is so thrown back that mere projecting tubercles would not suffice, we find them transformed into actual hooks (Fig. 5, *s* and *E*); while in some of the *succincti* they are little more than a thickening of the anterior margin of the subjoint. In all Lepidopterous pupæ these remnants of the anal prolegs are more or less indicated, while in certain moths (*Pterophoridæ*), where the pupa is partly suspended as it is in the *Nymphalidæ*, they are covered with long hooks similar to those at the tip of the cremaster and to those which, in the larva, armed the hind plantæ.

Thirdly. We have what may be called the *sustentor ridges* (*sr*), usually connected with the sustainers, and embracing them on the

outside, and extending backward to the inside of the ventral cremastral ridges, and sometimes, as in *Paphia* (Fig. 5, *B*) and *Limenitis*, there forming quite a deep notch, which doubtless assists in catching hold of the larval skin in the efforts to attach the cremaster. These sustentor ridges are homologous with the limb of the anal prolegs, and the exposed edge with the posterior border of said limb. They vary much in form, and may be more or less obsolete.

Fourthly. Between them is what may be called the *rectal piece* (*rp*), consisting of a piece more or less well marked and elevated, especially around the closed rectum.

It is principally by the leverage obtained by the hooking of the

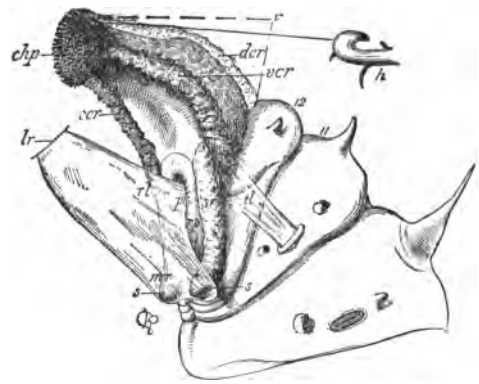


FIG. 4.— Anal parts of chrysalis of *Vanessa antiopa*, just prior to final extraction from shrunken larval skin: *c*, cremaster; *chp*, cremastral hook-pad; *h*, one of the hooks more enlarged; *vcr*, ventral cremastral ridge; *dcr*, dorsal cremastral ridge; *lr*, larval rectum; *pr*, pupal rectum; *rp*, rectal plate; *sr*, sustentor ridges; *s*, sustentores; *mr*, *membrana retinens*; *rl*, rectal ligament; *tl*, tracheal ligament; the 11th or last spiracle bearing joint and the 12th joint being numbered. (After Riley.)

sustainers in the retaining membrane, which acts as a swinging fulcrum, that the chrysalis is prevented from falling after the cremaster is withdrawn from the larval skin. It is also principally by this same means that it is enabled to reach the silk with the cremastral hook-pad. Yet the rectal ligament plays a most important part, and in some species a more important part even, in my estimation, than the membrane itself. The tracheal ligaments, which, from a study of specimens plunged in alcohol when the larval skin was about half shed, I was at first inclined to believe

important auxiliaries, are, I am now satisfied, of very little or no service in most cases. The rectal ligament is a constant physiological factor, and its importance cannot be ascertained by attempts to sever the membrane at the critical moment, because in such attempts the ligament is more or less drawn out beyond the power of the sphincter muscles in the chrysalis to control it.

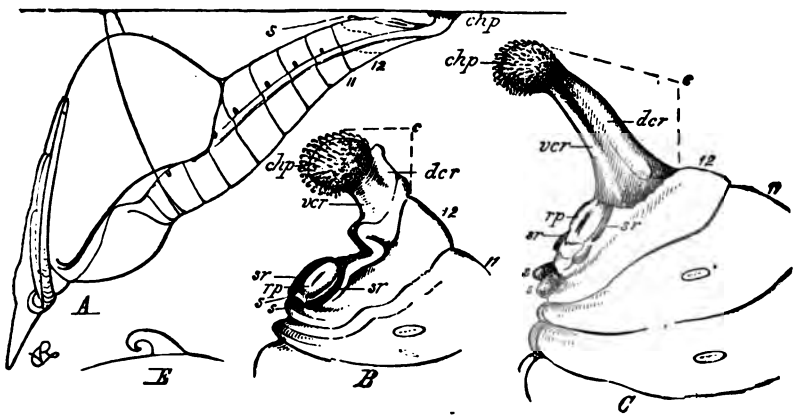


FIG. 5.—*A*, chrysalis of *Terias; B*, posterior end of chrysalis of *Paphia; C*, do. of *Danais; E*, one of the sustainers of *Terias*, greatly enlarged to show its hooked nature; all the parts of subjoint lettered to correspond with Fig. 4. (After Riley.)

Dissected immediately after suspension, the subjoint of the larva will be found to be bathed, especially between the legs and around the rectum, in an abundance of translucent, membranous material. An hour or more after suspension the end of the forming chrysalis begins to separate from the larval skin, except at the tip of the cremaster (see Fig. 6, *b*). Gradually the skin of the legs and of the whole subjoint stretches, and with the stretching, the cremaster elongates, the rectal piece recedes more and more from the larval rectum, and the sustentor ridges diverge more and more from the cremaster, carrying with them, on the sustainers, a part of the soft membrane. If a larva be carefully dissected at this stage, the forming membrane may be raised with the point of a needle and stretched so as to show its connection with the rectal ligament (Fig. 6, *d*); or it may be lifted entirely from the retainers, when, by its elasticity, it contracts and be-

THE COTTON WORM IN THE UNITED STATES. By CHAS. V. RILEY, of Washington, D. C.

[ABSTRACT.]

THE paper records some of the scientific results of inquiry respecting the Cotton Worm and other insects injurious to the cotton plant, begun by Prof. Riley while entomologist to the Department of Agriculture, and now being continued by him under the auspices of the U. S. Entomological Commission. Among the incorrect statements that have hitherto been made, and opinions that have obtained, regarding the habits of the Cotton Worm, the author mentions, 1st, that as to the first appearance of the young worms as late as the last of June, or later in the season in the canebreak country of Alabama; 2nd, the so-called sudden appearance of the worms in great numbers over large districts; 3rd, the idea that there are but three annual generations; 4th, the belief that the species has no parasites.

Three of these opinions were iterated in an interesting paper read by Prof. A. R. Grote, at the 1874 meeting of the Association, and were emphasized by the announcement that the paper was based on a residence and experience of five years in cotton growing States. Prof. Riley finds that the opinions are erroneous in that, *first*, the young worms hatch in April in southern Georgia and Alabama; that *secondly*, the first generation appears in spots, generally in such small numbers as to be easily overlooked, and that in subsequent generations the worms disperse, and increase, more or less rapidly, according as the surrounding conditions are favorable or otherwise; that, *thirdly*, there are from six to eight annual generations in the southern portion of the cotton belt; and that, *fourthly*, the species is attacked by at least ten distinct parasites, some of which are quite efficient in keeping it in check. In addition to two not yet reared to the perfect state, the following are enumerated:

From the egg of Aletia—*Trichogramma pretiosa*, n. sp.; from both larva and pupa—*Tachina aletiæ*, n. sp., and *Sarcophaga sarraceniæ* Riley; from the pupa alone—*Pimpla conquisitor* (Say), *Cryptus nuncius* Say, *Chalcis ovata* Say, *Cirrospilus esurus*, n. sp., and *Didictyum* (n. gen.) *zigzag*, n. sp.[1]

[1] These species have since been described in *Canadian Entomologist* (Vol. XI, p. 162) and *Bulletin 3 of the U. S. Entomological Commission.*

Regarding the theory of the annual dying out of the insect in the States, and the consequent annual migration of the moth thereto from some exotic country, Prof. Riley states that it was first suggested by Mr. Robert Chisholm of Beaufort, S. C., but first fully propounded in 1848 by Dr. D. B. Gorham in DeBow's Review.[2] In 1854 it was again set forth by Dr. W. I. Burnett in the Proceedings of the Boston Society of Natural History. The facts collected during the past year strengthen the belief that the moth hibernates with us, and that no such theory is necessary to explain the phenomena connected with its annual development. Its comparative absence during some years and its prevalence in injurious numbers during others, are dependent on the same natural conditions which govern the same phenomena in many species injurious to vegetation, and notably in the case of the Northern Army Worm (*Leucania unipuncta*).

Prof. Riley finds it convenient to divide the cotton belt into 1st, the southern or permanent portion, where the first worms annually appear and the moths in all probability hibernate; 2nd, the northern or temporary portion, in which the insect does not hibernate, but into which it spreads, either by gradual dispersion or by more sudden migration, from the permanent portion. The dividing line between these two portions must needs be difficult to define, because there is an uncertain region that may, according to season or circumstance, belong to either, and also because of the limited observations that have yet been made. Taking the early appearance of the worms as a basis, the southern portion may be thus roughly defined: Beginning with Texas, it includes the region south of the Galveston, Harrisburg and San Antonio Railroad, excluding perhaps the extreme western portion, but extending somewhat farther north along the river bottoms. In Louisiana and Mississippi it includes the valley of the Mississippi river and its tributaries, with uncertain northern limits. In Alabama it is represented by the limestone cotton belt south of Montgomery, though probably extending farther to the east of that point. In Georgia it does not extend north of Albany on the west, but doubtless includes the sea-islands along the coast, as also those of South Carolina, though at the present time cotton cultivation is limited to Saint Catharine's Island. In Florida it includes all parts where cotton is grown.

[2] Vol. III.

While the theory of annual immigration does not apply to the first or southern portion, Prof. Riley believes that it does apply to the northern portions, and that the insect is there killed out each winter; so that some of Prof. Grote's arguments have force if restricted to this more northern portion of the belt.

The interesting fact is recorded that the cotton plant furnishes not only the natural food of the larva, in the leaf; but likewise that of the moth, in a sweet liquid exuding from certain glands on the underside of the leaf, and at the base of the outer lobes of the involucre; also that the tip of the proboscis in the moth is admirably adapted to penetrate ripe fruit and that much injury is done to such by the moth. The fact that the first worms of the season usually appear in certain low, moist spots in a field, is explained by the sweet exudation being most copious and most attracting the parent moths there; also by the greater scarcity in such places of ants, which are very abundant in cotton fields and destructive to the worm, when young, or moulting, or enfeebled from whatsoever cause; while the more rapid development and multiplication of the insect during moist or rainy weather are explained by the decreased efficiency of its natural enemies. Aside from the parasites mentioned, the worm is beset on all sides by enemies which cannot work so well during wet weather, and whenever the natural checks are hindered in their work the great proficiency of the plant-feeder soon gives it the advantage in the struggle for existence. The conclusion is also arrived at, from certain futile attempts to introduce the English sparrow into the South, that this bird cannot be acclimated there, and that while it will extend into the cotton belt during winter time it returns farther north in summer, and dies when the temperature exceeds 100° Fahrenheit.

On a New Predaceous Lepidopterous Insect.

By J. Henry Comstock, of Washington, D. C.

While studying a colony of the cottony maple scale (*Pulvinaria innumerabilis*, Rathvon), which was found on a branch of *Negundo aceroides* in Washington, I was surprised to find a Pyralid

larva living within the cottony mass excreted by one of these insects. On farther examination it was found that very many of the bark-lice afforded retreats for similar larvæ. This, with the fact that the eggs deposited by such individuals, or the young lice developed from them had been destroyed, indicated that the Pyralid

larvæ were predaceous. One of these larvæ was placed in a glass tube with a bark-louse, the eggs of which had not been destroyed. These eggs had just hatched and the cottony excretion was swarming with the young lice. The larva soon made its way under this mass, and after spinning a delicate silken tube about its body began to devour the young lice greedily. The larva was placed in the tube at 3 P. M.; at 9 A. M. the following day it was found that fully one-third of the lice had been destroyed, showing that if these larvæ occur in great numbers they must prove an efficient check to the spread of this pest of our shade trees. It is an interesting fact bearing upon this point that as yet this bark-louse has not become common in Washington. Careful search revealed only a few sporadic individuals except upon a single box-elder tree; and there the predaceous caterpillars were so numerous that it was with difficulty that any scales were found not infested by them.

Although the caterpillar is well protected, living as it does within the mass of cottony excretion, it spins about its body a delicate silken tube. This tube reminds one of that spun by Galleria; but it is more delicate; and when spun within the cottony mass, it is with difficulty distinguished from it. When a branch is thickly infested by *Pulvinaria* these tubes extend from one bark-louse to another. The caterpillars are very active, moving freely about within these silken passages from beneath one scale to another.

At the time my observations were made (June 24th) many of the caterpillars were full grown, and some of them transformed at once. The cocoon is made within the silken tunnel and is quite delicate, the pupa being plainly visible within it. Individuals of this brood remained ten days in the pupa state. The greater number of the moths bred by me this year issued July 17th; some, however, did not appear until August 13th.

These moths are not easily disturbed; but will suffer the twig, upon which they are, to be handled freely without moving; and often they will not take to flight even when touched. They usually rest upon the two posterior pairs of legs and the tip of the folded wings, with the front pair of legs drawn closely to the body, and the whole body forming an angle of about 45° with the object upon which they are at rest. In this position they will remain motionless for hours.

Can it be that the slowness with which the coccid can spread has influenced the habits of this species in the adult state?

Several of the moths which issued July 17th were placed in a breeding-cage containing a twig infested with *Pulvinaria*. July 12th several eggs were found. These eggs were deposited singly either on the bark, the coccid scales, or the cottony masses. In the latter case they could scarcely be detected by the naked eye on account of their resemblance in color to the excretion. Six days after oviposition the eggs hatched.

I was unable to trace the history of the second brood for want of eggs or young bark-lice with which to feed the larvæ. It is probable, however, that the habits of this brood are similar to those of the first. I am strengthened in this belief from the fact that I found newly hatched *Pulvinaria* the day before the second brood of the *Pyralid* emerged from the egg.

This moth belongs to the genus *Dakruma* of Grote. And as the species seems to be undescribed, I propose for it the name *coccidivora*.

DAKRUMA COCCIDIVORA, n. sp.— *Expanse*, 10-18 mm. *Length of body*, 4-8 mm. ♂ ♀.—Head above dark ash-gray with a faint coppery reflection, below and behind the eyes white. Eyes black and quite coarsely faceted. Lower surface of antennæ pale brown; upper surface dark gray with coppery and green reflection. Labial palpi black sprinkled with white scales, and with the base almost entirely white. Maxillæ rust red with the basal half clothed with white scales interspersed with a few black ones. Thorax above, and patagia dark gray with brown and green reflection. Abdomen annulated with brown and light gray; the brown predominating above, the light gray beneath. Fore wings light gray marked with brown and black. A light band extends across the outer part of the basal third of the wing; the costal half of this band is wide, reaching nearly to the base of the wings; the remaining half is narrow. Near the base of the wings there is a short transverse gray band which is sometimes obsolete; exterior to this is a short longitudinal black spot, which also varies greatly in size and intensity of color. The light band which extends across the outer part of the basal third of the wing is bordered externally by a dark band, which is narrow on the costal, and near the middle of the wing widens so as to reach the outer third of the wing. There are two black discal spots which are sometimes distinct but more often united so as to form a single crescent-shaped spot opening outward. The markings of the outer third of the wing resemble greatly those of *Acrobasis nebulo*, there being a row of six or seven dark spots on the outer margin, and one-fourth of the distance to the body a wavy light gray band parallel to the exterior margin, and bordered on each side with dark brown; the costal end of the outer of these brown borders is usually darker and widened externally forming a conspicuous black triangular spot. Lower surface of the front wings dark gray especially toward the apex, with a faint brassy tinge. Hind wing light gray with the apex clouded.

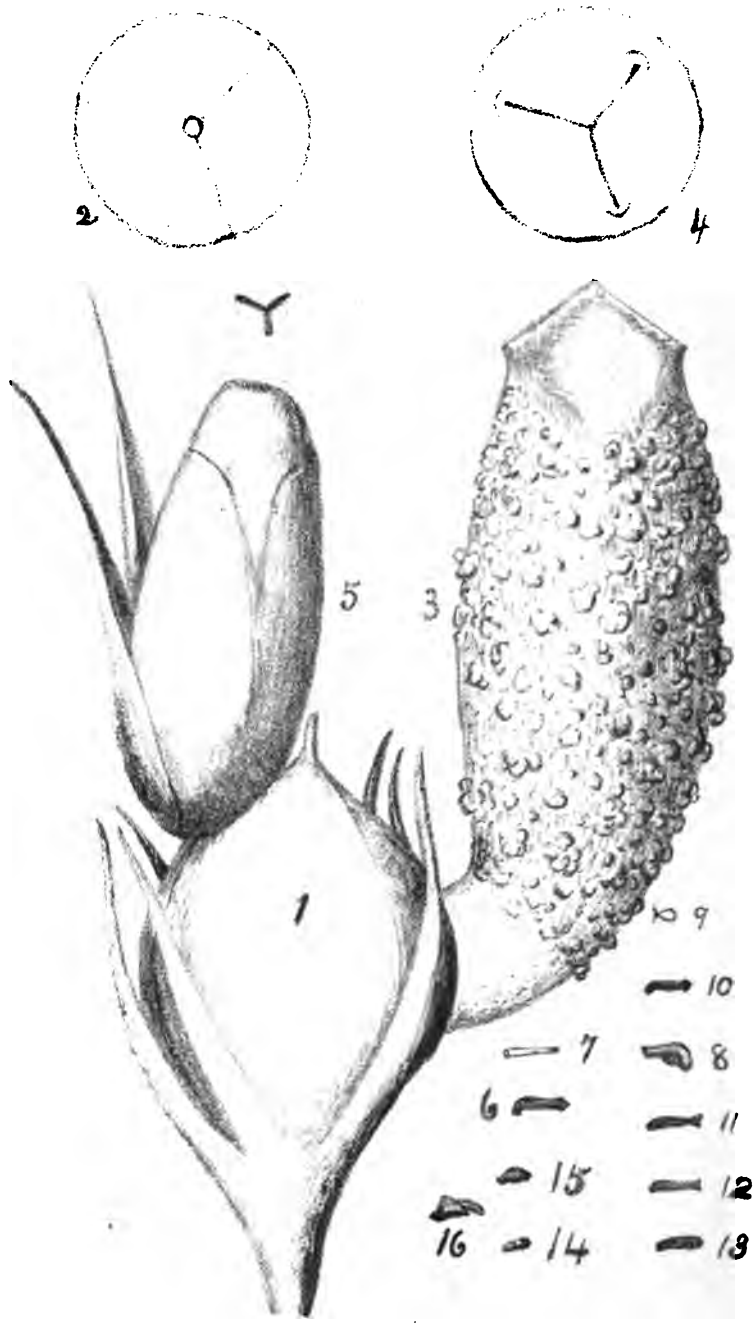
34 specimens examined, 18 ♂ 16 ♀.

Chrysalis.— Length, 6·5 mm. Color, dorsum dark brown inclining to blackish toward anus, venter a little lighter, wing and antennal sheaths yellowish-brown. Wing sheaths reaching nearly to the sixth abdominal segment; antennal sheaths reaching to the tip of the wing sheaths; dorsum densely punctured, venter less so; stigmata at the

Some interesting Insect-habits and their development. By W. S. Barnard, of Ithaca, N. Y.

During the past few months I have made observations on some interesting insect-habits, which urge me to think we can explain for them a mode of origin and development. This I wish to illustrate by examples. Perhaps there is no habit more curious among insects than that of *case-bearing by larvæ*, wherein the young insect wears clothing, which it finds ready made or makes by patchwork or by spinning alone. There are several insects which have this habit in their larval days. These protections for the body are tubular, conical, pyramidal, straight, curved, spiral, oval, triangular or flattened, often rude but sometimes very artistic in form and construction. They are produced in sub-groups of the orders Neuroptera (caddis-worms), Lepidoptera (Coleophora, etc.) and Coleoptera (Coscinoptera, etc.). Some cases are made by agglutinating together foreign substances, as dirt, excrements, fragments of stones, twigs, etc., others are of loose materials bound together by silk fibre, with or without a soft lining spun within, while others still consist entirely of silk. The habit exists with members of different orders very distantly related, hence we naturally suppose it has been acquired independently in different groups, and this mode of acquisition I wish to explain.

In the vicinity of Ithaca, N. Y., are several species of terrestrial and aquatic case-bearers. Among these I have become especially interested in one which is a young tineid moth (*Coleophora*). I have found it plentiful, in August, September and October, feeding on the seed-capsule and seeds of *Juncus*, a kind of rush, which grows on woody knolls. This season it has destroyed most of the seeds of that plant. One of the seed-capsules is shown in Fig. 1, with the brown, perfected larva-case (Fig. 3) mounted on it, magnified forty times. This completed case is about 5 mm. long and 1.50 mm. thick. I have also another species of the same genus from the same plant, having similar habits and form, but its case has no external granulation and is about 8.50 mm. long (see Fig. 6). Further developments are necessary before the species can be determined with certainty. These I hope to learn in the coming season. They are not noticed in Mr. Chambers' lists of the *Tineina* and their food-plants (Bull. Geol. and Geogr. Survey, Vol. IV, No. 1, 1878). But it is probable that one of these is new



BARNARD,—INSECT HABITS

The Heliotype Printing Co. 211 Tremont St. Boston

and that the other will prove to be *C. cæspititiella* Zell., which inhabits various species of Juncus in Europe, where the moth flies in May.

Let us notice the peculiarities of the case before us. It stands vertical with its mouth bound firmly to the seed-case. Thus the larva is head downwards with its abdomen elevated and entirely encased. It can conceal itself completely in the sheath alone, but when creeping its head and legs project while it carries itself erect or horizontal. The case adheres quite firmly, but when suddenly jerked loose we find the larva extending partly into the hole it gnaws, for, while its case is thus fixed immobile, it eats out the seeds. Finally, in autumn it must hunt some protected place to hibernate in its little house, for the moth will not appear until spring. It may be found in the crevices of bark on the trees near its food, and sometimes it creeps two meters high or more. A microscopic inspection of the case shows it to be made of densely woven lavender colored silk so that it really is a very warm overcoat. Outside of this, granules of its excrement are attached over the surface, for what purpose is not certain, yet we might fancy it may be to prevent its fellows from mounting on it and to make it an unpleasant morsel for voracious enemies. But the attachment of these pellets is in the first instance seemingly accidental from their adhesive coating and being emitted upwards so they must roll down the sides of the cylindriform habitation and are thus liable to cling unintentionally to all parts of the surface except to the lower constricted portion where they do not occur. The muzzle is curved at right angles with the body-axis to enable it to stand parallel against the side to which it attaches, and to protect the insect more fully when it creeps. On the bark of trees I find it adhering inversely, the round orifice being upward and fixed by an opercular web of silk. The rear end of the case is closed by a tricuspid valve (Fig. 4), that is, it ends in three lobes brought together to close up its aperture. Through the resultant trifid fissure the excrements are passed out.

Now this case is gradually produced during the growth of the larva. I have the younger cases in various grades of formation. And the trifid hole or valve aperture has been derived by every mature case from the earliest case. This valve-device and the whole case, despite the wonderful adaptation, design and beneficence here appearing, are not something devised by the insect or

any immediate intelligence, but are purely accidental to it, a result of the accidental conjunction of things. This seems a startling assertion, but we shall see. The young moth, before it has built a case, eats downward in a seed-capsule devouring the seeds, until it has cut through into the stem (receptacle) which is thereby severed. And all at once our young urchin is surprised at finding his head in the daylight while his body is clothed by the freed seed-case. While he still clings to his old home, he walks until he finds another fruit on which to pitch his tent. Into this he gnaws, and eating, grows. The case which he stole from the seed is young and small like himself, but, while it withers and shrinks, he outgrows it. As it attempts to go to pieces he binds the parts together. To enlarge it he opens the side and then darns over the gap. It becomes too short and he elongates it backward with his silk (Fig. 5). Gradually he enlarges it and lines it thus until finally a silk structure is completed while the original fragments of the seed-capsule are lost or become concealed, and he has a beautiful garment. The original pattern he got by accident. The seed-case breaks open as a tricuspid valve (Fig. 2) and this valve also was adopted from the plant. So it primarily got a case with a tricuspid valve and became a case-bearer, by an accident, without possessing any foresight or intention, for the design or pattern was not its own but that in a preëxisting seed-case. The after-modifications were gradual results of its growth and preëstablished mode of life. Of course a protective and hence selective advantage exists in the use of this habitation, yet both are only the mechanical outgrowth of a fortuitous conjunction of unintended experiences.

Thus the case-making and case-bearing habits, like habits generally, and the peculiar forms of the cases, like other natural forms, originate as mechanical results accidental to the creature, with no intelligence, foresight, purpose or design on its part, it being actuated by the blind impulse of instinct, which is inherited habit, originated and recurring as a reaction or as reflex-action mechanically resulting from the conjoined coöperating organization and environment.

In this connection it is also a remarkable, significant fact that in the order *Coleoptera* the larval beetles of the sub-family *Cryptocephalides* (which are case-bearers) in the first instance wear their tough portable egg-shell as a protective case, and afterward gradu-

ally enlarge upon it during growth until the original finally becomes a mere speck in the large completed artificial case. So far as the larva is concerned the original case is an accident to it. The males of these beetles and other enemies would devour their young upon their leaving the tough, distasteful shell. Hence those alone survive which are so shy as not to leave it, but only protrude the head and legs to draw them in quickly at the approach of danger. Among all their reflex acts, those of this kind are protective, selectively preserving from destruction the varieties in which they result. Will not this habit also, of keeping the head hidden by the larva, help explain, as resultant, the distinctive characteristics of the adult forms of the sub-family of *Cryptocephalides* "concealed-headed," as the name signifies, the head being drawn back deeply into, and, in the mature beetle, hardened and firmly fixed almost concealed in the prothorax? If so, we may then conclude also that the habitual functional usage of the form and structure involved has modified their growth and development, thereby giving origin to these morphological features and to the family established on them.

The young of the genera *Saxinis*, *Anomœa*, *Babia*, *Cryptocephalus*, *Coscinoptera* and *Chlamys*, have the above named habit and the egg shell thickened by a tough noxious extract, which prevents the males from devouring the eggs and young. Thus we account mechanically for the origin of cases on those insects. The use of excrements for rendering the bodies of the young distasteful and protecting them, occurring also in allied genera, may have originated in these before case-wearing, and is in combination with it for the purposes of preservation. I have studied specimens of the last three genera at Ithaca, N. Y., during the past summer with great interest and have been especially impressed with my observation of the way in which *Coscinoptera dominica* gnawed through its egg-cover (as has also been previously seen by Riley, 6th Rep. 1874, p. 129), to sever it as a portable case from its long pedicel, as a parallelism with the way in which our *Coleophora* severed and used the Juncus-capsule; while in both, the larval case becomes the pupal cocoon, although not made for that purpose, so that we here have examples of the origin and development of two kinds of cases and cocoons, which, as with the several other kinds of cases and cocoons, may have their origin and

development mechanically explained by a knowledge of the facts, as I intend to show hereafter.

In addition to the propositions already stated we need finally to assert that in insects belonging to widely different orders, similar habits have originated independently but under similar conditions.

Leaving now the explanatory part of this paper, I wish brief attention, in this connection, to a few other allied tineid moth-cases studied this season, mostly of the same genus, *Coleophora*, and further illustrating the case-bearing habit. The following stages and variations I have noticed, which may indicate only the phases of development of one or more species, occurring during the autumn on our hickory leaves and branches. Each is made by a leaf miner which eats in between the dermal layers of cells and then detaches the cellular laminæ surrounding it as a case. All agree in having the rear end of the case flattened with a two-lipped valve-orifice from the marginal edges of its two side-pieces remaining here disconnected. The larva of one (*C. caryæfoliella?*) continues mining the leaf by projecting into it but withdraws entirely into the case when disturbed.

No. 1 represents (*Aspidisca lucifluella* Clem.) the lowest type of case (Fig. 15). It has an irregular elongated oval form about 2.50 mm. long and is carried flatwise on the leaf. When severed from the leaf a thin layer of cells is still left beneath it.

No. 2 is similar but comparatively narrow and long (3 mm.), while one edge is nearly straight and the other curved. Fig. 14 shows one with a hole in its side, for I have observed that this and No. 6 are thus sometimes perforated by a hole like that in the scale of the apple bark louse by an enemy (*Aphelinus mytilaspidis?*), which destroys the larva.

No. 3 is about twice as long as No. 2. Its valve-end is rounded (Fig. 13), while its other outlines are nearly straight and its oval orifice opens nearly at right angles to the long axis. It differs from No. 1 also in being carried edgewise.

All the preceding show perfectly the venation and light brown color of the leaf on their surfaces, which are much dimmed or concealed in the following kinds by the added internal and external coatings making them very dark.

No. 4 is flat behind and cut off square while the rest of it is

somewhat narrower and cylindriform as shown in Fig. 12, with a total length of 7 mm.

No. 5 is the same except the valve end which is notched as in Fig. 11.

Both Nos. 4 and 5 vary from light to dark brown.

No. 6 is found on the branches chiefly and it is doubtful if it can be of the same species as the preceding ones. It is very black and differs from the others also in having a crooked neck while the flattened valve-lobes are triangular with one point directed backward as in Fig. 10. The valve is bicuspid and the whole form (Fig. 10) is more slender than in the first *Juncus* species. Its length is about 6.50 mm. Leaving now the hickory,

No. 7 is known as *Aspidisca splendoriferella* Clem. It has appeared late in autumn very plentifully on some of our apple trees, where it hibernates beneath the branches in its little flat obovate purse, which is fixed (to the bark) pendent on a short mass of silk (see Fig. 9).

No. 8 is a very odd form (Fig. 8) having the same color, construction and length as No. 6, but is strikingly peculiar in form, resembling a pistol, its valve-end being bent down like the handle, while the barrel-part sags a little in its middle, the muzzle is not curved and a lobate prominence represents the trigger-guard. I found it on chestnut bark in August and Mr. Chambers, who has made a specialty of these tineid moths, writes that he met with it in southern Kentucky, but could not rear the adult to determine its species.

For convenience in reference hereafter, I wish to assign the No. 9 to the short, brown, granulate tricuspid case (Figs. 3 and 5) on *Juncus*,

No. 10 to the long, smooth, brown tricuspid case (Fig. 6) of the same and No. 11, to a third kind (Fig. 7) on the same, consisting entirely of silk, being very light colored and transparent. It measures in length 7 mm. The valve is not tricuspid but a rather shapeless hole, sometimes with its margins pulled together to form two lips. Its neck is long and only slightly crooked. The muzzle is attached to a capsule. The whole is cylindriform, tapering smaller backward. The larva is sometimes entirely within the capsule and at others entirely in the sheath, which has a beautifully transparent glassy appearance.

Nos. 1–7 inclusive are formed of two similar pieces of leaf-

dermis with their margins neatly cut and joined by a viscid secretion and silk, but the two pieces united in No. 8 have a laminated striate appearance more resembling bark, yet respecting the nature of which I cannot now decide; but it may possibly be of bark, and from a species which I have recently discovered making very long winding, girdling mines in the superficial cell-layers of the young bark-dermis of chestnut trees. I do not find *bark-dermis miners* in the complete lists of miners and their food-plants by Chambers and Kaltenbach, but they certainly exist and I have specimens of these and of still another species working similarly in the green bark-dermis of dogwood (*Cornus*).

THE BUD-BLIGHT INSECT. BY W. S. BARNARD, of Ithaca, N. Y.

A SUMMARY topical statement of the contents of this paper may be presented thus. 1. Description and prevalence of bud-blight in pear-trees. 2. Its existence and cause apparently unknown and overlooked; but now determined as *Psylla pyrisuga* Foerst. 3. How ascertained. 4. Illustrations and description of the insect, its stages, habits and relationships. 5. Resultant injuries, serious and extensive. 6. Its friends, enemies and prevention. 7. Knowledge needed.

My attention has been attracted by a great absence of pear-buds and by certain terminal enlargements of pear twigs. Early last June the buds could be seen blighting and falling off. It could be observed to some extent on most of the pear trees in the neighborhood of Cornell University, at Ithaca, N. Y., while a few of the trees became almost entirely deprived of buds. In and about Saratoga, during this meeting, I have noticed the same, and the ruin of one orchard within three blocks of this hall is just now being completed.

By careful study throughout the summer, I have determined the cause of this bud-blight, with some other facts of interest and value pertaining to it.

My specimens here show the absence of buds and the terminal swelling and dying of the twigs. When the buds of vigorous

growing trees are destroyed, growth in an axial direction is impossible, so the accumulation of sap, and attempt to heal, result in these expansions, which are rather rare while the lack of buds is common.

In all pear-blights there appears a fungus, but its development can only be occasioned by some injury, as from excessive freezing or dryness and from the ravages of animals. When from climatic influences, usually a large part or all of the tree is affected at once; and the same may appear from animal injuries to the trunk or root. When parts of branches blight, its cause is often the blight-beetle, *Scolytus pyri*, boring within the part affected, and should be destroyed with it. If the leaves alone blight, with thickened blotches, which turn brown or black, the cause is in mites which burrow in their pulp. In all these cases the injury is easily observed, but the death or absence of the buds only, while the leaves remain green, cannot be attributed to any of the influences named and is generally overlooked; hence I wish to call especial notice to it, and request information, from all parts of the country, for it is very desirable to be able to make known the exact extent of its distribution and the resultant damages.

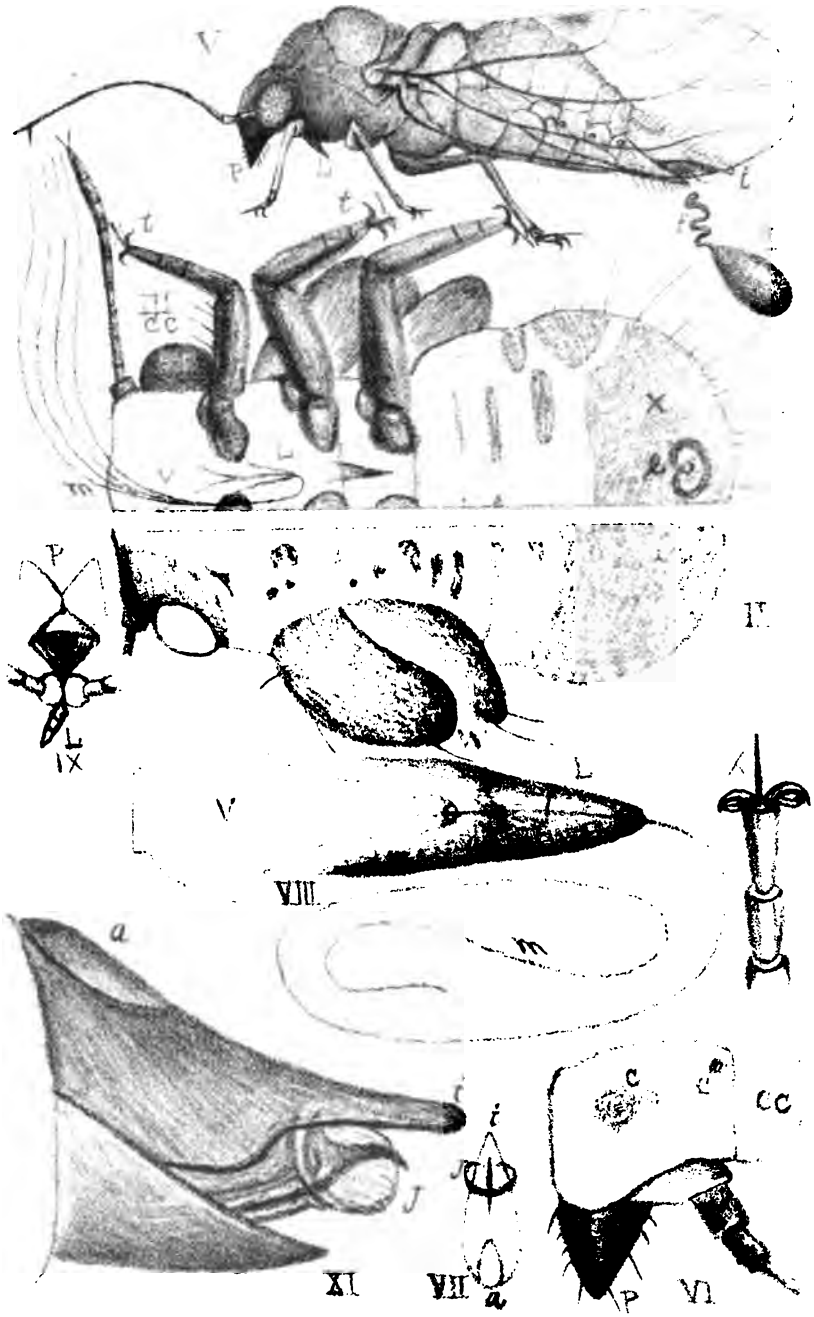
Buds are sometimes destroyed by gnawing insects, as cutworms and certain other caterpillars, but the fresh-cut surface, where the bud is recently removed, distinguishes their work from that in question, for here the bud and surfaces are all dry before the bud falls, while buds in all stages of dying occur.

I find the cause of this malady is a very inconspicuous creature, the *Psylla pyrisuga* Foerst., which is an old offender in Europe and has already received some attention in our country under the name of an allied foreign species, *Psylla pyri* L. Although studying the bud-blight and these insects at the same time, I did not at first attribute it to them, for where the buds were falling I generally found no Psyllas. But after watching their work for a long time I was able to detect it wherever buds were falling and found that the insects often all left before the buds fell off. Sometimes the only trace remaining would be a larval skin attached beneath a leaf near by. Also, there may be a sweetish taste to the surfaces on which they eject a secretion like the honey-dew of common plant-lice, which tastes very nice and may be still sought by ants or other insects after the bud-lice have gone. Again a dark color on the twigs or leaves in some instances has resulted where they

have been very abundant and dust has adhered to the once sticky surfaces. This hardened honey-dew is a varnish and may be of some injury by closing many respiratory pores.

It may be popularly named the pear-sucker as its specific name implies, or more appropriately, from its habits and appearance, the bud-louse; for its larvæ associate about the buds, and by their form and coloring so closely mimic the small buds and bud-scales as to be often scarcely distinguishable from them. They are also likely to be overlooked because, unless in very great abundance, their presence will not be indicated by any unhealthy appearance of the tree or its leaves until after they are gone, and they will usually have left the buds before they fall, so the general injury to the tree may only first appear in the following season.

Belonging to the order Hemiptera, sub-order Homoptera and family Psyllidæ of Burmeister, their form and structure relate them closely to the common plant-lice, *Aphididæ*, and to the bark-lice, *Coccidæ*, while they have the general appearance of minute cicadas or seventeen-year locusts. In size, each is quite diminutive, being only about 2.50 mm. long to the tip of the folded wings. Having gradual or incomplete metamorphosis, its three chief phases are, 1, the egg (Fig. I); 2, the larva (Figs. II and III); and 3, the adult (Fig. V). In the general form of the body we notice, as peculiar, the high upward swelling of the thorax while the region between the eyes is compressed from above downward and the abdomen is rather short if we exclude the ovipositing organs. The three posterior segments bear distinct stigmata (Fig. XI $_{000}$). The mouth-organs are united to form a three-jointed sucking beak (Figs. III, VIII and IX, *L*) which, in the adult, is rather short, but, in the larva, has its bristle-like jaws (*m*) as long as the body. This, the larva inserts about the bases of the buds, as a driven pump to suck out the sap, its food. I find that the four extremely long bristle-like jaws (maxillæ and mandibulæ) of the larva are cast off and lost with the last moulted skin. These are sheathed at their base by the three-segmented, tubular lower lip (*L*). When moving about the piercer is thrown backward toward the chest (thorax). In front of it the triangular upper lip (Figs. VIII, IX and III, *v*) appears as a plate pointing backward to between the fore legs. Still farther forward the adult has two quite large conical protuberances (Figs. V, VI and IX, *P*) and the fissure between them extends upward dividing the forehead. The



BARNARD.—BUD-BLIGHT INSECT.

The Heliotype Printing Co. 211 Thirteenth St. Boston

purpose of these organs we can only conjecture. They are probably feelers, for the sense of touch, but not homologies of palpi. As organs of sense, although the pigment is not developed in them, they seem, by their relative position, to represent those equally curious sub-ocular pigmented tubercles of the apple bark-louse (*Mytilaspis pomicorticis*) which, Riley and Signoret agree, subserve the power of sight. Mr. Riley has figured these in the male louse and writes thus: He has no proboscis (having lost it when shedding the larval skin), but near the place where it naturally would be are a couple of ocular tubercles, which give him the appearance of having four eyes — two above and two below (5th Rep., 1873, p. 84 and Fig. 31, *a*). These exist also in *M. Harrisii*, for I have observed them in its pupa. Burmeister has figured (Entomologie, Taf. II, Fig. 2, *a*) in *Coccus adonidum*, besides the two pairs of eyes (upper and lower) which characterize this genus, also just such conical processes as occur in *Psylla pyrisuga* Foerst., and asserts (Vol. 2, p. 63) that "the mouth does not exist in the male bark-lice, while with many, there are observed two black tubercles on the under side of the head." Comparing these cases with that of our Psylla we may conclude that homologous protuberances exist in both, and these in the bark-lice are often connate with a lower pair of eyes. We shall see that there are also other indications of close relationship between these animals and the bark-lice. Our larva may represent the bark-louse stage of *Psylla pyrisuga*, from its resemblance to the larval and female bark-lice. The simulation is not only in general form and mode of life, but also in some other important details. The anal shield (Figs. II and III, *x*) is a marked characteristic of both. The mouth apparatus lost before the adult stage is by its form and extremely backward position alike in both; and the antennæ resemble each other somewhat. Although the two terminal spines of the antennæ are a family characteristic for the adult and larval Psyllas, I believe I have observed the same in the youngest larval stage of *M. Harrisii* and in a larval *Limothrips mali*. The earliest and lowest distinct number of antennal divisions is also the same for *Psylla* and *Mytilaspis*. The proximal and distal antennal segments are enlarged. Only seven segments are distinct in the young *Psylla* while the adult has ten. The last three are not distinctly indicated in the larva and hence constitute but one from which three arise. Similarly, the third segment is hardly separable in

the larva while it develops the distinct ones within. This is well seen where larvæ about to moult have been mounted in a preservative fluid which causes them to shrink so that the final skin is drawn away from the larval skin, rendering their articulations easily comparable. The mature antennæ are slender and each has its distal portion of a dark color. They insert in front of the large, oval, compound eyes. On the head between the eyes are dark spots regarded as ocelli (Fig. VI *c*), constituting two pairs and often a third pair only partly separate from the innermost pair. The limbs are adapted for walking and springing, the hind ones especially strong, and all the femurs are thickened enabling it to jump like a flea.

There are three black spurs also at the lower extremity of the rear tibia, and two on its upper tarsal segment. As in the larva, there are two tarsals, and the feet (Fig. X) are peculiarly armed with a bilobed adhesive disk and two stiff lateral bristles while a larger third bristle and two strong hooks are united and retractile. These are probably withdrawn when the suckers are in use. Do these movable parts represent a third and rudimentary segment? The young cannot jump like the adults, but creep about slowly. The contrast between the adult and the flat larva in form and actions is very marked, but necessary to adapt them to their respective modes of life. The lobate wings of the advanced larva stand horizontally while the wings of the parents slope roof-like. When it springs it usually takes flight with its two pairs of excellent wings, which have a strong brownish-yellow venation (Fig. V) and are otherwise not colored except a dark spot (pterostigma) above the back (abdomen), it being quite large on the fore wings and more like a marginal band on the hind ones. By strong magnifying power, the thorax and head are seen to be beautifully mailed by imbricated, cycloid scales. The general color of this insect is variously given by different authors. During the summer I find at the same time adults differing much in color, so I presume each undergoes some changes of tint after attaining maturity. The change seems to be from a very light color to greenish-yellow, then to orange and finally to reddish-brown variegated with crimson, light yellow and green, while in some all these colors become very dark. I have often seen the sexes united standing side by side, but the males are very much less numerous than the females. The ovipositor (Figs. V and VII and XI) is rather complex, and is composed of two shields, one above, the other below, enclosing

other parts, very much as the parts of a bird's bill enclose its tongue. These anal plates as seen from above or below are lanceolate, while in profile the lowest one resembles the under part of a bird's beak, and the upper one is more peculiar, the middle part of its lower margin making a marked curve downward and its upper outline showing a slight upward swelling (*a*) with a depressed boundary surrounding it near the abdomen. When viewed from above and highly magnified, this boundary looks as if doubly milled, this appearance arising from a structure beneath and resembling a double layer of cells, the outer ones cuboid, the inner much elongated in form (Fig. VII, *a*). It reminds us of the singly milled margin (Fig. III, *e*) of the larval vent, but differs essentially. What excites interest at once is that this figure has just the same size and outline as the egg, wherefore we may presume that it is an organ for forming a thin outer coat on the egg and perhaps also for producing that viscid, fibrous prolongation of the egg by which it gains a firmer attachment. The shape of the egg (Fig. I) is seen to be nearly that of a common hen's egg. It lies upon its side, not erect or pendent on its fibre. Looking again from above there may be seen beneath the apical part a pair of thin, delicate, concave lobes (J) on a longitudinal shaft. These parts with other side pieces, which probably serve as guides, are seen again in the side-view. The size and form of the lobes suggest that they are to be drawn forward to grasp the large front end of the egg and push it backward. The anal organs are rather pointed, and, like those of some related genera, are accused of injuring the trees by perforating their parts so as to cause deformations, etc. Since the eggs are placed on the surface, there appears no purpose for such work, and if the apparatus may have been once designed and used for it, as appears with its relatives, it has probably lost the habit completely, and I do not find the malformations described. Also the outer plates are well set, even to their points, with hairs which are very long and strong on the upper one and seem to oppose their use for piercing. Hence I judge that statements like the following are not based on observation, but only ascribe to this creature the habits of some of its relatives. "The females are provided with a sharp, awl-like instrument at their hinder extremity, with which they pierce the buds and leaves and therein deposit their eggs. This operation often gives rise to small swellings or excrescences,

which serve as indications of the places affected by them."—Uhler, U. S. Agr. Rep., 1860, p. 314. The eggs (Fig. I) have been described as oval, yellow and resembling pollen grains. They are so small as to be barely visible without a microscope and are hard to find. They generally appear like yellow particles of dust scattered on the felty surfaces of the twigs or leaves, chiefly near the veins where the adults are also most commonly seen. On magnifying them highly, I find that each has a transparent fibre extending from its apex as an attachment to the part on which the eggs are laid.

The larva on leaving the egg is yellowish-white and creeps about slowly without any essential change of form, except in the development of lobate winglets, until the last slough, whereby it attains the mature state. For this final moult they go out underneath the leaves where their skins are left. Soon after hatching, the color changes to a brownish bark-color marked with the yellowish white background appearing in bands. They have an average size 1.50 mm. long and 1 mm. wide (Figs. II and III). During earliest life there exudes a waxy fibre which often forms a mesh, observable with the microscope, on the plant, probably to help secure the feeble young more safely. Besides using the sap to nourish themselves, they must also consume a great quantity to manufacture that sweet glandular secretion, the honey-dew, which they squirt on the plant. This attracts other insects, but chiefly the ants, which also serve as their protectors against enemies. The ants attend and milk them as affectionately as they do the aphides. Honey-dew is also yielded by the adults. The broad, semicircular, abdominal shield is one of the greatest peculiarities of these larvæ. Its margin bears thick hollow hairs, which probably are elongated honey-dew pores. Similar hairs occur on the margins of other parts. The larvæ are the injurious forms and seem to make a specialty of destroying the buds by sucking the sap near and about their bases. Even when sparse, the harm is great, because it then works so gradually that it is pretty sure to escape notice while the fatal results follow, though slowly, yet with certainty. It is known that apple trees are sometimes slightly affected by this pest as I have also observed. This year (1879) the most damage was done in the spring. During and after July, chiefly scattered individuals and few groups were found. But on a few trees, especially those near some large ants' nests, they continued abundant until late in

the fall. They seem to exist in all stages at all times during the summer, and now in the middle of November, when this MS. is going to press, I find a few larvæ. It is claimed in Europe that the females hibernate under the bark and lay their eggs in the spring. I am not sure of this, but think the eggs may hibernate also. As soon as the buds expand, it is said that the adults apparently begin to deposit their eggs. Thus it is seen that they work and reproduce constantly throughout the whole season. Now the character and extent of its work with us, as well as its history in the Old World, shows that the damages resulting from this insect are very serious and liable to be all-extensive in the United States. According to Dr. Harris (1855), it was imported from Europe in 1833 on young pear trees by one Dr. Plumb of Salisbury, Conn., for whom it destroyed several hundred trees in a few years (1834–8) and had afterwards spread into some neighboring counties of New York, Massachusetts and Connecticut. It has continued to adapt itself to withstand the American enemies and climate and to distribute itself more widely. Now it has already reached many other states and the prospect is that it is being conveyed elsewhere through the shipping of nursery stock and its own migrations. At present it is the worst enemy the pear tree has in our region and is likely to become such throughout the country. Dr. Plumb reported that most of the trees destroyed for him died during the next summer after the attack.

Any person not acquainted with the insect would naturally, I think, have attributed it to blight. I have in some instances noticed blight to propagate itself from the dying buds and to kill the branch in the same season, and I have no doubt that this insect may often be the remote cause of otherwise unaccounted-for blights of branches or whole trees. Most of our diseased pear trees show that it has prevented their growth in past years, also in the many dead-ended and shrubby-ended branches. It deserves as much attention from pear-growers as does the Phyllocera from grape cultivators. Like this insect it prefers certain varieties of its food-plant more than others. These should be made known. Also its mode of hibernation and its friends and enemies need to be studied and practical preventions devised. In the spring I have noticed a small larva of *Limothrips* somewhat augmenting the injuries done by the bud-louse. Most ordinary enemies of the plant-lice prey

on it, especially the young lady-birds and lace-wings, while a red mite probably spoils its eggs. The young do not usually occur in groups large enough to sustain the development of the blind Syrphus-fly maggots so destructive to most plant-lice. In general, I judge that its season will be longest and most successful where it is well protected by ants, whose nests should be sought and ruined. I have concluded that the good done by ants as scavengers is much more than balanced by their cultivating the herds of various kinds of plant-lice which are such a great damage to our vegetation, hence the ants should be destroyed invariably when not of value in fertilizing flowers. The adult *P. pyrisuga* Foerst. is so quick as to escape from all enemies. The young larvæ may be eradicated by a stiff brush, except from the leaf and bud axils. When once well established on many trees this manual work would be too great to undertake, but is to be recommended when they are first becoming introduced or when they are scarce in the spring, especially on the young and dwarf trees which they seem to prefer. In applying insecticides we must remember that they do not eat and therefore will not take in solid or liquid remedies. Hence it is necessary to use volatile poisons which may be inhaled by them. These are quite numerous and the most effective should be placed on the parts inhabited. We cannot be sure which is the best way to combat these insects until we are positive how they hibernate. If they winter in the crevices of the bark the remedies should and could be applied there in winter with excellent results. The following will prove efficacious if persistently and thoroughly applied: soap, benzine, coal oil, turpentine, coal tar. Most of these should be applied in a state of strong solution with water. One part of benzine or coal oil to ten of water will do well. And they will be of still greater value if mixed with sulphur flour or lime to form a whitewash.

With the request that general attention be given to this little pest and that information concerning it be addressed to the Entomological Department of Cornell University at Ithaca, N. Y., I hope that our knowledge of it may become much improved.

TITLES OF OTHER PAPERS READ IN SECTION B.

ON THE ANTHRACITE COAL FIELDS OF PENNSYLVANIA AND THEIR RAPID EXHAUSTION.[1] By P. W. SHEAFER, of Pottsville, Pa.

ON THE ANATOMY OF PLATHELMINTHS. By CHAS. SEDGWICK MINOT, of Boston, Mass.

ON THE HISTOLOGY OF INSECTS. By CHAS. SEDGWICK MINOT, of Boston, Mass.

ON THE MOLLUSCAN DREDGINGS IN THE GULF OF MEXICO AND VICINITY BY THE U. S. COAST SURVEY STEAMER BLAKE IN 1877–9. By WM. H. DALL, of Washington, D. C.

ON THE FERTILIZATION OF YUCCA. By THOMAS MEEHAN, of Germantown, Pa.

OBJECTS OF SEX AND OF ODOR IN FLOWERS. By THOMAS MEEHAN, of Germantown, Pa.

THE NEWLY-DISCOVERED CAVE IN LURAY, PAGE CO., VA. By JNO. W. CHICKERING, JR., of Washington, D. C.

THE ETHNICAL INFLUENCES OF PHYSICAL GEOGRAPHY. By DANIEL WILSON, of Toronto, Canada.

TWO INSTANCES OF APPARENT DISINTERESTEDNESS AMONG ANIMALS. By BURT G. WILDER, of Ithaca, N. Y.

NOTES ON THE ANATOMY OF THE CAT'S BRAIN. By BURT G. WILDER, of Ithaca, N. Y.

ON A CAT'S BRAIN WITH THE CORPUS CALLOSUM ABSENT OR UNDIFFERENTIATED. By BURT G. WILDER, of Ithaca, N. Y.

FROZEN SECTIONS OF THE CAT PRESERVED IN ALCOHOL. By BURT G. WILDER, of Ithaca, N. Y.

PRACTICAL ILLUSTRATION OF THE USE OF SOME NEW OR LITTLE KNOWN ANATOMICAL AND PHYSIOLOGICAL INSTRUMENTS AND APPARATUS. By BURT G. WILDER, of Ithaca, N. Y.

[1] This paper has been printed by the author since the meeting.

RECENTLY DISCOVERED CUPREOUS VEINS AT BLUE HILL, ME. By C. H. HITCHCOCK, of Hanover, N. H.

THE GREEN MOUNTAIN ANTICLINAL. By C. H. HITCHCOCK, of Hanover, N. H.

THE INTEROCEANIC CANAL PROBLEM. By EDWARD P. LULL, of Washington, D. C.

ON A REMARKABLE CRINOIDAL FORM RECENTLY DISCOVERED IN TENNESSEE, WITH EXHIBITION OF SPECIMENS. By JAMES M. SAFFORD, of Nashville, Tenn.

ON THE THINNING OUT AND ABSENCE OF UPPER SILURIAN AND DEVONIAN FORMATION IN TENNESSEE. By JAMES M. SAFFORD, of Nashville, Tenn.

ON THE GEOLOGY OF PORT HENRY, N. Y. By T. STERRY HUNT, of Montreal, Canada.

CONSONANTAL EXPRESSION OF EMOTION. By CLARENCE J. BLAKE, of Boston, Mass.

THE FAUNA OF THE LOWER HELDERBERG GROUP, IN RELATION TO THE CORALS BRYOZOA AND ECHINODERMATA. By JAMES HALL, of Albany, N. Y.

NOTES UPON THE GENERA FENESTELLA, HEMITRYPA, ETC. By JAMES HALL, of Albany, N. Y.

ON THE GENUS PLEUROTOMARIA. By WM. H. DALL, of Washington, D. C.

ON THE GEOLOGY OF BERMUDA. By WM. NORTH RICE, of Middletown, Conn.

SEXUAL DIFFERENTIATION IN EPIGÆA REPENS. By LESTER F. WARD, of Washington, D. C.

HOMOLOGIES IN THE LAURACÆA. By LESTER F. WARD, of Washington, D. C.

NOTE ON THE MOVEMENT OF THE STAMENS OF SABBATIA ANGULARIS. By LESTER F. WARD, of Washington, D. C.

ON THE PRESENT CONDITION OF THE WORK UPON THE PALÆONTOLOGY OF NEW YORK. By JAMES HALL, of Albany, N. Y.

THE DEVELOPMENT OF THE NEURATION IN THE WINGS OF INSECTS, AS ILLUSTRATED IN THE HISTORY OF COCKROACHES. By S. H. SCUDDER, of Cambridge, Mass.

COLORS AND DEFECTIVE VISION. By D. G. CROLY, of New York, N. Y.

GYPSUM SAND. By A. P. S. STUART, of Lincoln, Nebraska.

AN APPARATUS FOR PHOTOGRAPHING NATURAL HISTORY OBJECTS IN A HORIZONTAL POSITION. By S. H. GAGE, of Ithaca, N. Y.

A SUCCESSFUL MOTH-TRAP. By W. S. BARNARD, of Ithaca, N. Y.

ON THE PROGRESS OF THE SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA. By J. P. LESLEY, of Philadelphia, Pa.

ON THE TRIASSIC ROCKS OF NEW JERSEY. By GEO. H. COOK, of New Brunswick, N. J.

A NEW FORM OF UNPOLARIZABLE ELECTRODES FOR PHYSIOLOGICAL RESEARCH. By H. P. BOWDITCH, of Boston, Mass.

THE GENESIS OF THE SERPENTINE OF REICHENSTEIN, ETC. By R. B. HARE, of Ontario, Canada.

ON THE SURFACE LIMITS OF THICKNESS OF THE CONTINENTAL GLACIER, IN NEW JERSEY. By J. C. SMOCK, of New Brunswick, N. J.

PERMANENT

SUBSECTION OF ANTHROPOLOGY.

PAPERS READ.

THE SIGN LANGUAGE OF THE NORTH AMERICAN INDIANS. By GARRICK MALLERY, U. S. Army, Washington, D. C.

WHILE the study of the Sign Language of the North American Indians is, for reasons to be suggested, of special utility, it claims general interest from its illustration of the ancient intercommunication of mankind by gesture. Many arguments have been adduced to prove that the latter preceded articulate speech. The corporeal movements of the lower animals to express, at least, emotion, have been correlated with those of man, and classified by Darwin as explicable on the principles of serviceable associated habits, of antithesis and of the constitution of the nervous system. A child employs intelligent gestures long in advance of speech, although very early and persistent attempts are made to give it instruction in the latter but none in the former, and long after familiarity with speech, it consults the gestures and facial expressions of its parents and nurses as if to translate or explain their words: which facts are important in reference to the biologic law that the order of development of the individual is the same as that of the species. Persons of limited vocabulary, whether foreigners to the tongue employed, or native but not accomplished in its use, even in the midst of a civilization where gestures are deprecated, when at fault for words resort instinctively to physical motions that are not wild or meaningless, but picturesque and significant though perhaps made by the gesturer for the first time; and the same is true of the most fluent talkers on occasions when the exact vocal formula desired does not at once suggest itself or is not satisfactory without assistance from the physical machinery not embraced in the oral apparatus. The signs used by uninstructed congenital deaf-mutes and the facial expression and gestures of the congenitally blind also present considerations under the heads of heredity and atavism. In conjecturing the first attempts of man, or his hypothetical ancestor, at the expression either of percepts or concepts, it is difficult to connect vocal

sounds with any large number of objects, but readily conceivable that there should have been resort, next to actual touch, to suggest the characteristics of their forms and movements, to the eye, fully exercised before the tongue, so soon as the arms and fingers became free for the requisite simulation or portrayal. Linguistic scholars have recently decided that the search for imitative, onomatopoetic and directly expressive sounds to explain the origin of human speech has been too exclusive, and that many holophrastic roots of language have been founded in the involuntary sounds accompanying certain actions; but as the action was the essential, and the consequent or concomitant sound the accident, it would be expected that a representation or feigned reproduction of the action would have been used to express the idea before the sound associated with that action could have been separated from it. There is also strong probability that in the pristine days when the sounds of the only words yet formed had close connection with objects and the ideas directly derived from them, signs were as much more copious for communication than speech, as the sight embraces more, and more distinct, characteristics of objects than does the sense of hearing.

For the present purpose there is, however, no need to determine upon the priority between communication of ideas by bodily motion and by vocal articulation, if it be but admitted that the connection between them was so early and intimate that the gestures in the wide sense indicated had a direct formative effect upon many words,—that they exhibit the earliest condition of the human mind,—are traced from the farthest antiquity among all peoples possessing records,—are universally prevalent in the savage stage of social evolution, and still adhere to the ordinary speech of civilized man by motions of the face, hands, head and body, often involuntary, often purposely in illustration or emphasis.

The power of the visible gesture relative to and its influence upon the words of modern oral speech are perhaps, though with the qualification hereafter indicated, in inverse proportion to the general culture, but do not bear that or any constant proportion to the development of the several languages with which gesture is still, more or less, associated. They are affected more by the sociological conditions of the speakers than by the degree of excellence of their tongue. The statement is frequently made that gesture is yet to some highly-advanced languages a necessary

modifying factor, and that only when a language has become so artificial as to be completely expressible in written signs—indeed, has been remodelled through their long familiar use—can the bodily signs be wholly dispensed with. The story has been told by travellers in many parts of the world that various languages cannot be clearly understood in the dark by their possessors, using their mother tongue between themselves. The evidence for this anywhere is suspicious, and when it is, as it often has been, asserted about some of the tribes of North American Indians, it is absolutely false, and must be attributed to the error of travellers, who, ignorant of the dialect, never see the natives except when trying to make themselves understood by their visitors, or perhaps when they are guarding against being overheard by others. In fact, individuals of those American tribes specially instanced in these reports as unable to converse without gesture, often, in their domestic *abandon*, wrap themselves up in robes or blankets, with only breathing holes before the nose, so that no part of the body is seen, and chatter away for hours, telling long stories. If in daylight they thus voluntarily deprive themselves of the possibility of making signs, it is clear that their preference for talks around the fire at night is explicable by very natural reasons wholly distinct from the one attributed. The inference, once carelessly made from the free use of gesture by some of the Numa stock, that their tongue was too meagre for use without signs, is refuted by the now ascertained fact that their vocabulary is remarkably copious and their parts of speech highly differentiated.

The true distinction is that where people speaking precisely the same dialect are not numerous, and are thrown into constant contact on equal terms with others of differing dialects and languages, gesture is necessarily resorted to for converse with the latter, and remains as a habit or accomplishment among themselves; while large bodies enjoying a common speech, and either isolated from foreigners, or, when in contact with them, so dominant as to compel the learning and adoption of their own tongue, become impassive in its delivery. The undemonstrative English, long insular, and now rulers when spread over continents, may be compared with the profusely-gesticulating Italians dwelling in a maze of dialects, and subject for centuries either to foreign rule or to the influx of strangers on whom they depended. The difference

in what is vaguely styled temperament does not wholly explain this contrast. As the number of dialects in any district decreases so will the gestures, though doubtless there is also influence from the fact, not merely that a language has been reduced to and modified by writing, but that people who are accustomed generally to read and write, as are the English and Germans, will after a time think and talk as they write, and without the accompaniments still persistent among Hindus, Arabs, and the less literate Europeans.

Instances are shown of the discontinuance of gesture-speech with no development in the native language of the gesturers, but from the invention for intercommunication of one used in common. The Kalapuyas of southern Oregon until recently used a sign-language, but have gradually adopted for foreign intercourse the composite tongue, commonly called the Tsinuk or Chinook jargon, that arose for trade purposes on the Columbia river before the advent of Europeans, founded on the Tsinuk, Tsihali, Nutka, etc., but now enriched by English and French terms, and have nearly forgotten their old signs. The prevalence of this mongrel speech, originating in the same causes that produced the pigeon-English or *lingua-franca* of the Orient, explains the marked scantness of sign-language among the Oregonian tribes.

When the specific practice of the sign language has been discontinued either from the adoption of a jargon or from the common use of the tongue of the conquering English, French or Spanish, some of the gestures formerly employed as substitutes for words may survive as a customary accompaniment to oratory or impassioned conversation and, when ascertained, should be carefully noted. An example, among many, may be found in the fact that the now civilized Muskoki or Creeks, when speaking of the height of children and women, illustrate their words by holding the hand at the proper elevation, palm up; but when describing the height of animals or inanimate objects, they hold the palm downward. This, when correlated with the distinctive signs of other Indians, appears to be an interesting case of the survival of a practice which the oldest men of the tribe only remember vaguely by tradition.

The assertion has been made by many writers, and is currently repeated by Indian-traders and army officers, that all the tribes of North America have had and still use a *common* and *identical* sign-language of ancient origin, in which they can communicate

freely without oral assistance. The truth of this remarkable statement, contradicting some canons of evolution, can only be tested by careful comparison of lists or sign vocabularies, taken at widely different times and places. For this purpose lists have been collated by the writer, taken in different parts of the country, at several dates from the last century to the last month, comprising together more than eight hundred signs, many of them, however, being mere variants or synonyms for the same object or quality.

The result of the collation and analysis thus far made is, that the alleged existence of *one* universal and absolute sign-language is, in its terms of general assertion, one of the many popular errors prevailing about our aborigines. In many instances there is an entire discrepancy between the signs made by different bodies of Indians; and if any of these are regarded as determinate, or even widely conventional, and used without further devices, they will fail in conveying the desired impression to any one unskilled in gesture as an art, who had not formed the same precise conception, or been instructed in the arbitrary motion. Very few of the limited number of gestures that are found in current use are in their origin conventional, but are only portions, more or less elaborate, of obvious natural pantomime, and those proving to convey most successfully the several ideas became the most widely adopted. Sometimes signs, doubtless once air-pictures of the most striking outline of an object, or of the most characteristic features of an action, have in time become abbreviated, and to some extent conventionalized, among members of the same tribe and its immediate neighbors, and have not become common to them with other tribes simply because the form of abbreviation has been peculiar. In other cases, with the same conception and attempted characterization, another, yet equally appropriate, delineation has been selected, and when both of the differing delineations have been abbreviated the diversity is vastly increased. The original conception, being independent, has necessarily also varied, because all objects have several characteristics, and what struck one set of people as the most distinctive of these would not always so impress another. From these reasons we cannot expect, without trouble, to understand the etymology of all the signs, being less rich in ancillary material than were even the

old philologists, who guessed at Latin and Greek derivations before they were assisted by Sanscrit and other Aryan roots.

It must be noted that in the study and analysis of all written descriptions of Indian signs there is danger lest the civilized understanding of the original conception may be mistaken or forced. The liability to error is increased from the fact that some of the collections are not taken directly from the Indians themselves, but are given as obtained at second-hand from white traders, trappers, and interpreters, who, through misconception in the beginning and their own introduction or modification of gestures, have produced a jargon in the sign as well as in the oral intercourse. If an Indian finds that his interlocutor insists upon understanding and using a certain sign in a particular manner, it is within the very nature, tentative and elastic, of the gesture art —both performers being on an equality—that he should adopt the one that seems to be intelligible or that is pressed upon him, as with much greater difficulty he has learned and adopted many foreign terms used with whites but never with his own race. Thus there is now, and perhaps always has been, what may be called a *lingua-franca* in the sign vocabulary.

The *attempt to convey meaning by signs is*, however, *universal* among the Indians of the plains and those still comparatively unchanged by civilization, as is its successful execution in a cultivated art, which consists in actually pointing out objects in sight, not only for designation, but for application and predication, and in suggesting others to the mind by action and the airy forms produced by action. It is very noticeable that the Indian signs are characterized by motion rather than by position, and that the motions are large and free, seldom minute.

In no other part of the world has there been spread over so vast a space so small a number of individuals divided by so many linguistic and dialectic boundaries. Many wholly distinct tongues have for a long indefinite time been confined to a few scores of speakers, verbally incomprehensible to all others on the face of the earth who did not, from some rarely operating motive, laboriously acquire their language. Even when the American race, so styled, flourished in the greatest population of which we have any evidence (at least according to the views of the present writer published in the Proceedings of this Association, Nashville Meet-

ing, Vol. XXVI), the immense number of languages and dialects still preserved, or known by early recorded fragments to have once existed, so subdivided it that but the dwellers in a very few villages could talk together with ease, and all were interdistributed among unresponsive vernaculars, each to the other being bar-bar-ous in every meaning of the term. It is, however, noticeable that the three great families of Iroquois, Algonkin, and Muskoki, when met by their first visitors, do not appear to have often impressed the latter with their reliance upon a gesture code to the same extent as has always been reported of those now and formerly found farther inland. If this absence of report arose from the absence of the practice and not from imperfection of observation, the latter being more probable, an explanation may be suggested from the fact that, among those families there were more people dwelling near together in sociological communities, of the same language, though with dialectic peculiarities, than became known later in the later West, and not being nomadic, their intercourse with strange tribes was less individual and conversational.

The use of gesture signs, continued, if not originating, in necessity for communication with the outer world, became entribally convenient from the habits of hunters, the main occupation of all savages, depending largely upon stealthy approach to game, and from the sole form of their military tactics — to surprise an enemy. In the still expanse of virgin forests, and especially in the boundless solitudes of the great plains, a slight sound can be heard over a vast area, that of the human voice being from its rarity the most startling, so that it is now, as it probably has been for centuries, a common precaution for members of a hunting or war party not to speak together when on such expeditions, communicating exclusively by signs. The acquired habit exhibits itself not only in formal oratory, but in impassioned conversation.

This domestic as well as foreign exercise for generations in the gesture-language has naturally produced great skill both in expression and reception, so as to be measurably independent of any prior mutual understanding, or what in a system of signals is called preconcert. Two accomplished army signalists can, after sufficient trial, communicate without either of them learning the code practised by the other, one being mutually devised for the occasion, and those specially designed for secrecy are often deciphered. So, if any one of the more approximately conventional

signs is not quickly comprehended, an Indian skilled in the principle of signs resorts to another expression of his flexible art, perhaps reproducing the gesture unabbreviated and made more graphic, perhaps presenting either the same or another conception or quality of the same object or idea by an original portraiture. A lesson was learned by the writer as to the abbreviation of signs, and the possibility of discovering the original meaning of those most obscure, from the attempt of a Cheyenne to convey the idea of *old man*. He held his right hand forward, bent at elbow, fingers and thumb closed sidewise. This not conveying any sense, he found a long stick, bent his back, and supported his frame in a tottering step by the stick held, as was before only imagined. There, at once, was age dependent on a staff. It is probable that none of the Indian signs are arbitrary, but that in them as in all his actions, man had at first a definite meaning or purpose, together with method in their after changes or modifications. The formation and reception of signs upon a generally understood principle, by which they may be comprehended when seen for the first time, is doubtless one explanation of the report of a common code, as out of a variety of gestures appropriate to express a particular idea, an observer may readily have met the same one in several localities. The same tribe has, indeed, in some instances, as appears by the collected lists, a choice already furnished by tradition or importation, or both together, of several signs for the same thought-object. Thus there are produced synonyms as well as dialects in the sign-language.

The general result is that two intelligent mimes seldom fail of mutual understanding, their attention being exclusively directed to express thoughts by the means of comprehension and reply equally possessed by both without the mental confusion of conventional sounds only intelligible to one. The Indians who have been shown over the civilized East have, also, several times succeeded in holding intercourse, by means of their invention and application of principles in what may be called the voiceless mother utterance, with white deaf-mutes, who surely have no semiotic code more nearly connected with that attributed to the plain-roamers than is derived from their common humanity. On one of the most interesting of these occasions, at the Pennsylvania Institution for the deaf and dumb in 1873, it was remarked that the signs of the deaf-mutes were much more readily understood

by the Indians than were theirs by the deaf-mutes, and that the latter greatly excelled in pantomimic effect. This need not be surprising when it is considered that what is to the Indian a mere adjunct or accomplishment is to the deaf-mute the natural mode of utterance, and that there is still greater freedom from the trammel of translating words into action — instead of acting the ideas themselves — when, the sound of words being unknown, they remain still as they originated, but another kind of sign, even after the art of reading is acquired, and do not become entities as with us.

Some examples have been selected of diverse conceptions and executions for the same object or thought.

Chief. Four distinct signs.

1. Forefinger of right hand extended, passed perpendicularly downward, then turned upward in a right line as high as the head. "Rising above others."

2. With forefinger of right hand, of which the other fingers are closed, pointing up, back to forehead, describe the flight of an arrow shot up and turning down again, allowing the hand to drop, the finger pointing down until about the middle of the body. Same idea of superior height expressed conversely. Almost the same sign, the hand however being moved downward rapidly and the gesture preceded by touching the lower lip with the index, the French deaf-mutes use for "command," "order."

3. Begin with sign for man; then the forefinger of right hand points forward and downward, followed by a curved motion forward, outward, and downward. "He who sits still and commands others."

4. Raise the index of right hand, which is held upright; turn the index in a circle and lower it a little to the earth. "He who is in the centre of surrounding inferiors." The air picture reminds of the royal sceptre with its sphere.

Day. Five signs.

1. Pass the index-finger pointing along the vault of heaven from east to west. Our deaf-mutes use the same sign.

2. Same motion with whole right hand.

3. Same motion with forefinger of right hand crooked, followed by both hands slightly spread out and elevated to a point in front of and considerably above the head, then brought down in a

semicircle to a level below the shoulder, ending with outspread palms upward. This, probably, is the opening out of the day from above, after the risen sun.

4. Simply make a circle with the forefingers of both hands. The round disk.

5. Both hands flat, backs before breast and separated. The French deaf-mutes fold the hands upon each other and the breast, then raise them, palms inward, to beyond each side of the head.

To-day, this day, has two widely discrepant signs in, at least, appearance. In one, the nose is touched with the index tip, followed by a motion of the fist toward the ground, — perhaps including the idea of now, here. In the other, both hands are extended, palms outward, and swept slowly forward and to each side. This may combine the idea of *now* with *openness*, the first part of it resembling the general deaf-mute sign for "here" or "now."

Death, dead. Four signs.

1. Right hand, fingers front at height of stomach, then, with a sort of flop, throw the hand over with the palm up, finger pointing a little to the right and front, hand held horizontal. "Upset, keeled over."

2. Left hand flattened and held, back upward, thumb inward, in front of and a few inches from the breast, right hand slightly clasped, forefinger more extended than the others, and passed suddenly under the left hand, the latter being at the same time gently moved toward the breast. "Gone under."

3. Hold the left hand flat against the face, back outward; then pass the right hand, held in the same manner, under the left, striking and touching it lightly. The same idea of under or burial, quite differently executed.

4. Throw the forefinger from the perpendicular into a horizontal position toward the earth with the back downward.

The French deaf-mute conception is that of gently falling or sinking, the right index falling from the height of the right shoulder upon the left forefinger, toward which the head is inclined.

Kill. In one sign the hands are held with the edges upward, and the right strikes the left transversely, as in the act of chopping. This seems to convey particularly the notion of a stroke with a tomahawk or war-club. Another sign: smite the sinister

palm earthward with the dexter fist sharply. Another: strike out with the dexter fist toward the ground. A fourth: pass the right under the left forefinger—"make go under." The threat," I will kill you," appears in one case as directing the right hand toward the offender, and springing the finger from the thumb as in the act of sprinkling water, the idea being perhaps causing blood to flow, or perhaps sputtering away the life, though this part of the sign is nearly the same as that sometimes used for the discharge of a gun or arrow.

Fear, coward.

1. Both hands, with fingers turned inwards opposite the lower ribs, then brought upwards with a tremulous motion, as if to represent the common idea of the heart rising up to the throat.

2. Head stooped down, and arm thrown up quickly as if to protect it.

3. Fingers and thumb of right hand, which droops downward, closed to a point to represent a heart, violently and repeatedly beaten against the left breast just over the heart to imitate palpitation.

The French deaf-mutes, besides beating the heart, add a nervous backward shrinking with both hands. Our deaf-mutes omit the beating of the heart, except for excessive terror.

4. Point forward several times with the index, followed by the remaining fingers, each time drawing the index back as if impossible to keep the man to the front.

Woman has four signs: one expressing the mammæ, one indicating shortness as compared with man, and the two most common severally indicating the longer hair or more flowing dress.

The deaf-mutes generally mark the line of the bonnet string down the cheek.

Quantity, many, much. Six wholly distinct executions and several conceptions.

1. The flat of the right hand patting the back of the left several times, proportioned in number to the quantity. Simple repetition.

2. Clutching at the air several times with both hands. Same idea of repetition, more objective.

3. Hands and arms passed curvilinearly outward and downward as if forming a large globe, then hands closed and elevated as if something were grasped in each, and held up as high as the face.

4. Hands held scoop-fashion, palms toward each other, about two feet apart, at the height of the lower ribs, finger-ends downward; then with a diving motion, as if scooping up small articles from a sack or barrel, bring the hands nearly together, fingers closed, as if holding a number of the small objects in each hand, and up again to the height of the breast.

5. Both hands closed, brought up in a curved motion toward each other to the level of the neck. Idea of fulness.

6. Move the two open hands toward each other, and slightly upward; the action of forming or delineating a *heap*.

I, myself, first personal pronoun.

Represented in some tribes by motions of the right hand upon the breast, the hand sometimes clenched and struck repeatedly on the breast,—or the fingers, or the index alone, placed upon it. Others touch the nose tip with the index, or lay it upon the ridge of the nose, the end resting between the eyes.

Some deaf-mutes push the forefinger against the pit of the stomach, others against the breast, and others point it to the neck for this personality.

Yes, affirmative, it is so.

One of the signs is somewhat like "Truth," but the forefinger proceeds straight forward from the breast instead of the mouth, and when at the end of its course it seems gently to strike something, as if the subject were at an end; no further discussion, "'nuff said," as is the vulgar phrase of agreement.

Others wave both hands straight forward from the face, which may be compared with the forward nod common over most of the world for assent, but the New Zealanders elevate the head and chin, and the Turks shake it like our negative.

With others, again, the right hand is elevated to the level and in front of the shoulder, the first two fingers somewhat extended, thumb resting against the middle finger, and then a sudden motion in a curve forward and downward. As this corresponds nearly with the sign made for "sit" by the same tribes, its conception may be that of resting upon or settling a question.

Good. Five diverse signs.

1. The hand held horizontally, back upward, describes with the arm a horizontal curve outward.

2. Simple horizontal movement of the right hand from the breast. These signs may convey the suggestion of level—no

difficulty—and are nearly identical with one of those for "content," "glad." The first of them is like our motion of benediction.

3. With the right hand, palm down, fingers to the left, thumb touching the breast, move the hand straight to the front and slightly upward.

4. Wave the right hand from the mouth, extending the thumb from the index and closing the other three fingers.

5. The right hand, fingers pointing to the left, on a level with mouth, thumb inward, suddenly moved, with curve outward, so as to present the palm to the person addressed.

These last signs appear to be connected with a pleasant taste in the mouth, as is the sign of the French and our deaf-mutes, waving thence the hand, back upward, with fingers straight and joined, in a forward and downward curve. The same gesture with hand sidewise is theirs and ours for general assent — "very well!"

Understand, *know*, is very variously expressed by manipulations in which the nose, ear, chin, and mouth are selected as objective points, all the motions being appropriate. *Think* or *guess* is also diversely indicated. Sometimes the forefinger is simply drawn across the breast from left to right. Again, the right fist is held with the thumb between the eyes and propelled front and downward. We, for show of thought, rest the forefinger on the forehead. There is also a less intelligible sign in which the right hand, fingers and thumb loosely closed, index extended crooked, is dipped over toward and suddenly forward from the right shoulder. All the gestures of deaf-mutes relating to intelligence are connected with the forehead.

Animals are expressed pantomimically by some characteristic of their motion or form, and the Indian mimographers generally seem to have hit upon the same sign for each animal, but to this rule there are marked exceptions in the *deer* and the *dog*. For the *deer* five signs are noted:

1. Right hand extended upward by the right ear with a quick puff from the mouth—perhaps in allusion to the fleet escape on hearing noise.

2. Make several passes with the hand before the face.

3. Forefinger of right hand extended vertically, back toward breast, then turned from side to side to imitate the motion of the animal when walking at leisure.

4. Both hands, fingers irregularly outspread at the sides of the head, to imitate the outspread horns. This sign is made by our deaf-mutes.

5. Same position, confined to the thumb and first two fingers of each hand.

For *dog*, one of the signs gives the two forefingers slightly opened, drawn horizontally across the breast from left to right. This would not be intelligible without knowledge of the fact that before the introduction of the horse, and even yet, the dog has been used to draw the tent-poles in moving camp, and the sign represents the trail. Indians less nomadic, who built more substantial lodges, and to whom the material for poles was less precious than on the plains, would not perhaps have comprehended this sign, and the more general one is the palm lowered as if to stroke gently in a line conforming to the animal's head and neck. It is abbreviated by simply lowering the hand to the usual height of the wolfish aboriginal breed, and suggests *the* animal *par excellence* domesticated by the Indians and made a companion. The French and American deaf-mutes more specifically express the dog by snapping the fingers and then patting the thigh, or by patting the knee and imitating barking with the lips.

Among the signs that are found generally current and nearly identical may be noted that for *horse*, made by the fore and middle finger of the right hand, placed by some astraddle of the left index, and by others of the edge of the left hand, the animal being considered at first as only serviceable for riding and not for draft. The French deaf-mutes add to the straddling of the index the motion of a trot. Our deaf-mutes indicate the ears, followed by straddling the left hand by the fore and middle fingers of the right.

Same, similar, which is made not only among all our tribes, but by those all over the world, and by deaf-mutes, by extending the two forefingers together side by side, backs upward, sometimes moved together slightly forward. When held at rest in this position, *companion* and the tie of fellowship, what in days of chivalry was styled "brothers in arms," can be indicated, and, as a derivative also, *husband*. The French and American deaf-mutes use this sign, preceded by one showing the sex, for brother or sister.

An opposition to this is given, though not generally reported,

for *he*, or *another person*, by placing one straight forefinger over the other, nearly touching, and then separated with a moderately rapid motion. The deaf-mutes for "he" point the thumb over the right shoulder.

The principal motion for *admiration*, *wonder*, consists in placing the right hand before the mouth, which is open, or supposed so to be — a gesture seemingly involuntary with us.

The general sign for *sun*, when it is given as distinguished from *day* — made by forming a circle with the thumb and forefinger raised to the east or along the track of the orb — is often abbreviated by simply crooking the elevated forefinger into an arc of a circle, which would more naturally be interpreted as the crescent moon. It appears that some tribes that retain the full descriptive circle for the sun do form a distinguishing crescent for the moon, but with the thumb and forefinger, and for greater discrimination precede it with the sign for *night*, which, with some occasional additions, is the crossing of both horizontally outspread palms, right above left, in front of the body, the conception being covering, shade, and consequent obscurity. With a slight differentiation, *darkness* is presented, and with another, *forget*, *forgotten*, that is, darkness in the memory.

While several conceptions and delineations have been mentioned for "good," those most common for *bad* consist mainly in smartly throwing out the dexter fingers as if sprinkling water, or snapping all the fingers from the thumb. This may be compared with the deaf-mute sign of flipping an imaginary object between the thumb-nail and the forefinger, denoting something small or contemptible. The motion of snapping a finger either on or from the thumb in disdain is not only of large modern prevalence in civilization, but is at least as ancient as the contemporary statue of Sardanapalus at Anchiale. Another less forcible but equally suggestive gesture for *bad* is closing the hand and then opening while lowering it, as if dropping out the contents; "not worth keeping." The deaf-mutes preserve the connection of bad and taste by brushing from the side of the mouth.

Inquiry, *question*,— What? Which? When?

This is generally denoted by the right hand held upward, palm upward, and directed toward the person interrogated, and rotated two or three times edgewise. When this motion is made, as among some tribes, with the thumb near the face, it might be mis-

taken for the derisive, vulgar gesture called "taking a sight," descending to our small boys from antiquity; but the separate motion of the fingers in the latter is more nearly correlated with the Indian sign for *fool*. The same rotation upon the wrist, with the index and middle finger diverged over the heart, means specifically *uncertainty*, *indecision*, "more than one heart for a purpose," and a variant of it appears in one of the signs for "*I don't know.*"

The Indian sign for "inquiry" is far superior to that of the French deaf-mutes, which is the part of the French shrug with the hunched shoulders omitted.

Fool, *foolish*. The prevailing gesture is a finger pointed to the forehead and rotated circularly — "rattle-brained." The only variance is where the sign for "man" is followed by shaking the fingers held downward, without reference to the head — the idea of looseness simply. French deaf-mutes shake the hands above the head after touching it with the index.

No, *negative*. The right hand — though in the beginning of the sign held in various positions — is generally either waved before the face (which is the sign of our deaf-mutes for emphatic negative), as if refusing to accept the idea or statement presented, or pushed sidewise to the right from either the breast or face, as if dismissing it or setting it aside. This may be compared with our shaking of the head in denial; but that gesture is not so universal in the Old World as is popularly supposed, for the ancient Greeks, followed by the modern Turks and rustic Italians, threw the head back, instead of shaking it, for *No*.

Lie, *falsehood*, is almost universally expressed by some figurative variation on the generic theme of a forked or double tongue — "two different stories" — in which the first two fingers of the right hand separate from the mouth. *Truth*, *true*, is naturally contradistinguished by the use of a single finger, the index, pointing straight from the mouth forward and sometimes upward — "One tongue; speech straight to the front; no talk behind a man." Sometimes, however, the breast is the initial point, as in the French deaf-mute sign for "sincere." The deaf-mutes also gesture "truth" by moving one finger straight from the lips — "straight forward speaking" — but distinguish "lie" by moving the finger to one side — "sideways speaking."

Offspring or descendant, child in filial relation — not simply as young humanity — is generally denoted by a slightly varied dumb

show of issuance from the loins, the line traced sometimes showing a close diagnosis of parturition. The sign, with additions, means father, mother, grandparent, but its expurgated form among the French deaf-mutes means parentage generically.

Possession, mine, my property. The essential of this common sign is clenching the right hand held at the level of the head and moving it gently forward, clearly the grasping and display of property. None of the deaf-mute signs to express "possession," "ownership," known to me, resemble this or are as graphic. Our deaf-mutes press an imaginary object to the breast with the right hand.

Steal. The prevalent delineation is by holding the left arm horizontally across the body and seizing from under the left fist an imaginary object with the right hand, implying concealment and the transportation that forms part of the legal definition of larceny. This sign is also made by our deaf-mutes. Sometimes the fingers of the right hand are hooked, as if grabbing or tearing. The specialty of horse-theft is indicated by the pantomime of cutting a lariat.

Trade, barter, exchange, is very commonly denoted by a sign, the root of which is the movement of the two flat hands or the two forefingers past each other, so that one takes the place before held by the other, the exact conceit of exchange. Our deaf-mutes use the same gesture with the hands closed. An invitation to a general or systematic barter or trade, as distinct from one transaction, is expressed by repeated taps or the use of more fingers. The rough resemblance of this sign to that for "cutting" has occasioned mistakes as to its origin. It is reported by Captain Burton as the conception of one smart trader cutting into the profits of another—"diamond cut diamond." The trade-sign is, on the plains, often used to express the *white man*—vocally named Shwop—a legacy from the traders, who were the first Caucasians met. Generally, however, the gesture for *white man* is by designating the hat, or head-covering of civilization. This the French deaf-mutes apply to all *men*, as distinct from women.

A few signs have been selected that are not remarkable either for general or limited acceptance, but are of interest from special conception or peculiar figuration.

The relation of *brothers, sisters,* and of brother and sister, chil-

dren of the same mother, is signified by putting the first two finger tips into the mouth, denoting the nourishment taken from the same breast. One of the signs for *child* or infant is to place the thumb and fingers of the right hand against the lips, then drawing them away and bringing the right hand against the left forearm as if holding an infant. The Cistercian monks, vowed to silence, and the Egyptian hieroglyphers, notably in the designation of Horus, their dawn-god, used the finger in or on the lips for child. It has, however, been conjectured in the last instance that the gesture implied, not the mode of taking nourishment, but inability to speak = *in-fans* An uninstructed deaf-mute, as related by Mr. Denison of the Columbia Institution, invented to express "sister" first the sign for "female," made by the half-closed hands with the ends of fingers touching the breasts, followed by the index in the mouth.

Destroyed, all gone, no more.

The hands held horizontal and the palms rubbed together two or three times circularly; the right hand is then carried off from the other in a short horizontal curve. "Rubbed out." This resembles the Edinburgh and our deaf-mute sign for "forgive" or "clemency," the rubbing out of offence.

Done, finished. The hands placed edges up and down, parallel to each other, right hand outward, which is drawn back as if cutting something. An *end* left after cutting is suggested; perhaps our colloquial "cut short." The French and our deaf-mutes give a cutting motion downward, with the right hand at a right angle to the left.

Glad, pleased, content. Wave the open hand outward from the breast, to express heart at ease — "bosom's lord sits lightly on its throne. Another gesture, perhaps noting a higher degree of happiness, is to raise the right hand from the breast in serpentine curves to above the head. "Heart beats high."

Dissatisfaction, discontent, is naturally contrasted by holding the index transversely before the heart, and rotating the wrist several times, indicating disturbance of the organ, which our aborigines, like modern Europeans, poetically regard as the seat of the affections and emotions, not selecting the liver or stomach as other peoples have done with greater physiological reason.

To *hide, conceal*, is graphically portrayed by placing the right

hand inside the clothing of the left breast, or covering the right hand, fingers hooked, by the left, which is flat, palm downward, and held near the body. The same gestures mean "*secret.*"

Peace, or *friendship*, is sometimes shown by placing the tips of the two first fingers of the right hand against the mouth and elevated upward and outward to mimic the expulsion of smoke — "we two smoke together." It is also often rendered by the joined right and left hands, the fingers being sometimes interlocked, and sometimes simply by hooking the two forefingers together. Our deaf-mutes interlock the forefingers for "friendship," clasp the hands, right uppermost, for "marriage," and make the last sign, repeated with the left hand uppermost, for "peace." The idea of union or linking is obvious. It is, however, noticeable, that while this ceremonial gesture is common and ancient, the practice of shaking hands on meeting, now the annoying etiquette of the Indians in their intercourse with whites, was never used by them between each other, and is clearly a foreign importation. Their fancy for affectionate greeting was in giving a pleasant bodily sensation by rubbing each other's breasts, arms, and stomachs. Our senseless and inconvenient custom of shaking hands is, indeed, by no means general throughout the world, and in the extent to which it prevails in the United States, is ludicrous.

The profession of *peace, coupled with invitation*, is often made from a distance by the acted spreading of a real or imaginary robe or blanket — "come and sit down."

The sign for *stone* has an archæological significance — the right fist being struck repeatedly upon the left palm, as would be instinctive when a stone was the only hammer.

Prisoner is a graphic picture. The forefinger and thumb of the left hand are held in the form of a semicircle opening toward and near the breast, and the right forefinger, representing the prisoner, is placed upright within the curve and passed from one side to another, in order to show that it is not permitted to pass out

Soft is ingeniously expressed by first striking the open left hand several times with the back of the right, and then striking with the right the back of the left, restoring the supposed yielding substance to its former shape.

Without further multiplying examples, the conclusion is presented that the gesture-signs among our Indians show no uniform-

ity in detail, the variety in expression among them and in their comparison with those of deaf-mutes and transatlantic mimes being in itself of psychological interest. The art is not a mere semaphoric repetition of arbitrary notions, but is founded upon principles which can be readily applied by travellers and officials so as to give them much independence of professional interpreters, a class generally deceitful and tricky. They thus would accomplish for themselves the desire of the Prince of Pontus, who begged of Nero an accomplished pantomimist to interpret among his many-tongued subjects. While thus of practical value, our native semiotics may help the archæologist in his study of picture-writing, the sole form of aboriginal records; for it was but one more step to fasten upon bark, skins, or rocks the evanescent air-pictures that still in pigments or carvings preserve their skeleton outline, and in their ideography approached the rudiments of a phonetic alphabet.

The reproduction of gesture-lines in these pictures seems to have been most frequent in the attempt to convey those subjective ideas which were beyond the range of an artistic skill limited to the direct representation of objects, so the part of the pictographs which is the most difficult of interpretation is precisely that which the study of the sign language is likely to elucidate. In this connection it may be mentioned that a most interesting result has been obtained in the tentative comparison so far made between the gesture signs of our Indians and some of the characters in the Chinese, Assyrian, Mexican and Runic alphabets or syllabaries, and also with Egyptian hieroglyphs.

While the gesture utterance presents no other part of grammar to the philologist besides syntax, or the grouping and sequence of its ideographic pictures, the arrangement of signs when in connected succession affords an interesting comparison with the early syntax of vocal language, and the analysis of their original conceptions, studied together with the holophrastic roots in the speech of the gesturers, may aid to ascertain some relation between concrete ideas and words. Thomas Aquinas said, "*Nomina debent naturis rerum congruere;*" and, surely, gestures being founded wholly on *nature*, with even yet slight artificial corruption, may explain the origin of the other nearly contemporaneous device of expression,—the visual onomatopœia illustrate the audible.

This study will be continued with special reference to the probable scientific results herein merely indicated.

It is the intention of the Bureau of Ethnology of the Smithsonian Institution to publish a collation in the form of a vocabulary, of all authentic signs, ancient and modern, found in any part of the world, with their description as also that of associated facial expression, set forth in language so clear that, with the assistance of copious illustrations, they can be reproduced by the reader. The success of this undertaking will depend upon the collaboration now requested of many persons of several classes. Arrangements probably sufficient to procure all the gesture-signs of the aboriginal tribes of this country which can still be rescued from oblivion have already been made. The conventional signs of deaf mutes in institutions for their instruction are accessible to the present writer, who also has obtained a large number of the natural signs of deaf mutes invented by them before systematic instruction and used in intercourse with their families and friends. More of these would, however, be gladly received. Further assistance is urgently sought from philologists, travelers and missionaries whose attention has been directed to the several modes of expressing human thought. Such efforts of all savage and barbarian tribes, when brought into contact with other bodies of men not speaking an oral language common to both, and especially when uncivilized inhabitants of the same territory are separated by many linguistic divisions, should, in theory, resemble the devices of the North American Indians. They are not shown by published works to prevail in the eastern hemisphere to the same extent and in the same manner as in North, and also, as believed from less complete observation, in South America. It is, however, probable that they exist in many localities, though not reported, and also that some of them survive after partial or even high civilization has been attained, and after changed environment has rendered their systematic employment unnecessary. Such signs may be, first, unconnected with existing oral language, and used in place of it; second, they may be used to explain or accen-

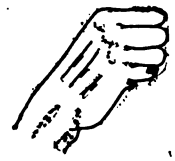
tuate the words of ordinary speech, or may consist of gestures, emotional or not, which are only noticed in oratory or impassioned conversation, such being, possibly, survivals of a former gesture language, as explained above.

All classes of gestures may be examined philologically to trace their possible connection with the radicals of language, syllabaries and ideographic characters. Even if the more material and substantive relations between signs and language cannot now be ascertained, from the inquiries suggested we may at least expect linguistic results in the analogy between their several developments. The mental processes are nearly the same in both cases, and the psychology of language may be studied in the older and lower means of communication as the physical and mental organization of man has been profitably compared with that of the lower animals. Not until a large body of facts has been gathered by several classes of observers, and compared by competent scholars, can it be possible to ascertain with precision the principles of the primitive utterance of mankind. An exhaustive treatment of the subject will also bring to light religious, sociologic and other ethnologic information of special interest. It is in this work that the Bureau of Ethnology of the Smithsonian Institution solicits the coöperation of learned men and observers in all lands whose contributions when received will always be published with individual credit as well as responsibility.

In order both to save labor and insure accuracy, sheets have been prepared containing the "TYPES OF HAND POSITIONS," "OUTLINES OF ARM POSITIONS" and "EXAMPLES" copies of which, to any requisite number, together with a pamphlet containing minute directions, and official stamps for return postage on communications, will be furnished on request mailed to the present writer at P. O. Box 585, Washington, D. C.

TYPES OF HAND POSITIONS IN GESTURE-LANGUAGE.

A — Fist, palm outward, horizontal.



B—Fist, back outward, oblique upward.

C — Clinched, with thumb extended against forefinger, upright, edge outward.

D—Clinched, ball of thumb against middle of forefinger, oblique, upward, palm down.

E—Hooked, thumb against edge of forefinger, upright, edge outward.

F—Hooked, thumb against side of forefinger, oblique, palm outward.

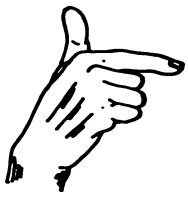
G—Fingers resting against ball of thumb, back upward.

H—Arched, thumb horizontal against end of forefinger, back upward.

I—Closed, except forefinger crooked against end of thumb, upright, palm outward.

J—Forefinger straight, upright, others closed, edge outward.

K—Forefinger obliquely extended upward, others closed, edge outward.



L—Thumb vertical, forefinger horizontal, others closed, edge outward.

M—Forefinger horizontal, fingers and thumb closed, palm outward.

N—First and second fingers straight upward and separated, remaining fingers and thumb closed, palm outward.

O—Thumb, first and second fingers separated, straight upward, remaining fingers curved edge outward.

P—Fingers and thumb partially curved upward and separated, knuckles outward.

Q—Fingers and thumb separated, slightly curved, downward.

R—Fingers and thumb extended straight, separated, upward.

S—Hand and fingers upright, joined, back outward.

T—Hand and fingers upright, joined, palm outward.

U—Fingers collected to a point, thumb resting in middle.

V—Arched, joined, thumb resting near end of forefinger, downward.

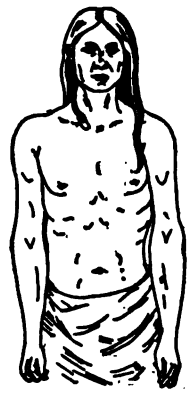
W—Hand horizontal, flat, palm downward.

X—Hand horizontal, flat, palm upward.

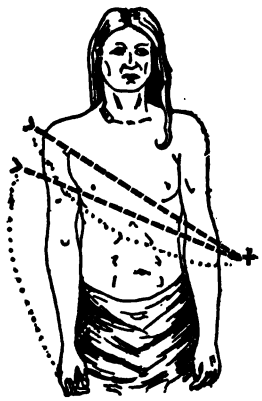
Y—Naturally relaxed, normal; used when hand simply follows arm with no intentional disposition.

N. B.—The positions are given as they appear to an observer facing the gesturer, and are designed to show the relations of the fingers to the hand rather than the positions of the hand relative to the body, which must be shown by the outlines (see sheet of "OUTLINES OF ARM POSITIONS," or description. The right and left hands are figured above without discrimination, but in description or reference the right hand will be understood when the left is not specified. The hands as figured can also with proper intimation be applied with changes either upward, downward, or inclined to either side, so long as the relative positions of the fingers are retained, and when in that respect no one of the types exactly corresponds with a sign observed, modifications will be made by pen or pencil on that one of the types found most convenient, as indicated in the sheet of "EXAMPLES," and referred to by the letter of the alphabet under the type changed, with the addition of a numeral—*e. g.*, A 1, and if that type, *i. e.*, A, were changed a second time by the observer (which change would necessarily be drawn on another sheet of types), it should be referred to as A 2.

OUTLINES FOR ARM POSITIONS IN GESTURE-LANGUAGE.



N. B.—The gestures, to be indicated by corrected positions of arms and by dotted lines showing the motion from the initial to the final positions (which are severally marked by an arrow-head and a cross—see sheet of EXAMPLES), will be always shown as they appear to an observer facing the gesturer, the front or side outline, or both, being used as most convenient. The special positions of hands and fingers will be designated by reference to the "TYPES OF HAND POSITIONS." For brevity in the written description, "hand" may be used for "right hand," when that one alone is employed in any particular gesture. In cases where the conception or origin of any sign is not obvious, if it can be ascertained or suggested, a note of that added to the description would be highly acceptable. Associated facial expression or bodily posture which may accentuate or qualify a gesture is necessarily left to the ingenuity of the contributor.



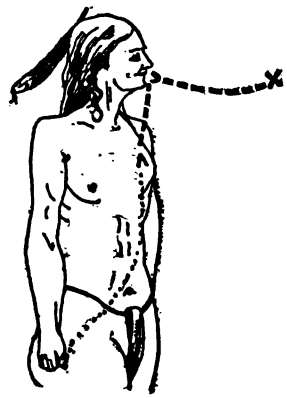
EXAMPLES.

Word or idea expressed by sign: To cut, with an axe.

DESCRIPTION:

With the right hand flattened (X changed to right instead of left), palm upward, move it downward to the left side repeatedly from different elevations, ending each stroke at the same point.

Conception or origin: From the act of felling a tree.



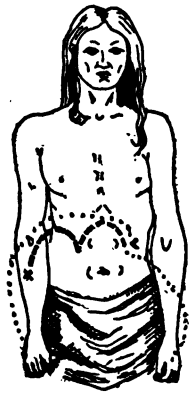
Word or idea expressed by sign: A lie.

DESCRIPTION:

Touch the left breast over the heart, and pass the hand forward from the mouth, the first two fingers only being extended and slightly separated (L, 1—with thumb resting on third finger).

Conception or origin: Double-tongued.

L, 1.



Word or idea expressed by sign: To ride.

DESCRIPTION:

Place the first two fingers of the right hand, thumb extended (N, 1) downward, astraddle the first two joined and straight fingers of the left (T, 1), sidewise, to the right, then make several short arched movements forward with hands so joined.

N, 1.

Conception or origin: The horse mounted and in motion.

T, 1.

Dotted lines indicate movements to place the hand and arm in position to commence the sign and not forming part of it.

> Indicates commencement of movement in representing sign, or part of sign.

Dashes indicate the course of hand employed in the sign.

× Represents the termination of movements.

Used in connection with dashes, shows the course of the latter when not otherwise clearly intelligible.

On the Explanation of Hereditary Transmission. By Louis Elsberg, of New York, N. Y.

There is no doubt that physical and also mental and moral traits are frequently hereditarily transmitted. Some persons go further than others in their estimate as to the extent to which such transmission takes place; but that it actually occurs, all admit.

Though the facts are recognized, their explanation is not known. I announced an hypothesis more than ten years ago, which I have twice, already, brought to the attention of the members of this Association.[1] By the acceptance of the Plastidule Hypothesis, the phenomena of heredity are brought a step nearer to our understanding.

Every vertebrate animal begins its existence in the form of a fecundated ovum. The ovum originates in the female body, and fecundation consists in the mixture with the ovum of the male semen or sperm: a mixture which in various animals has been actually observed.[2] All inheritance, whether direct, reversional, collateral or impressional, must therefore be transmitted by these two generative constituents, the ovum and sperm.

The most important generalization for which biology is indebted to the microscope was that inaugurated about forty years ago by Schleiden and Schwann, viz., that all organic bodies are composed of essentially similar form-elements. These were at first called "cells," as they were supposed to be vesicles with more or less

[1] "Regeneration or the Preservation of organic molecules; a contribution to the doctrine of evolution," Proceedings, Hartford Meeting, August, 1874, etc., "On the Plastidule Hypothesis," Proceedings, Buffalo Meeting, August, 1876.

[2] Although the introduction of the spermatic particles into the ovum is very difficult of observation, there are investigators who have seen this phenomenon repeatedly. Siebold, a master among masters, and an observer who never exaggerates his facts, has seen the spermatic particles within the yolk membrane of the bee's eggs more than twenty times, and has been able to show this to others. In the ova of the Nephelis, a small species of leech, Robin has seen spermatozoids to the number of several hundred penetrate the vitelline membrane, always at one point, and continuing their movements upon the surface of the vitellers. Almost always when the penetration has ceased, a bundle of spermatozoids is arrested in the micropyle. Although I have never succeeded in seeing the penetration myself, that does not diminish my confidence in the reports of those who have. Prof. Austin Flint, Jr., of Bellevue Hospital Medical College, says in his Physiology, published by Appleton, New York, that he "had an opportunity of witnessing a demonstration of these phenomena by Prof. Robin, in 1861, in the ova of the *Limnæus stagnalis*, and actually saw a spermatozoid half-way through the vitelline membrane." Coste, and many other observers whom it is unnecessary to quote, have seen the spermatozoid in the ovum of the rabbit, etc.

solid or fluid contents. Later investigations have shown that they are not always cells in any proper sense of that word, but the name was retained long after it was recognized to be generally a misnomer. Recently, however, the term "plastids" has come into use as a substitute, for the purpose of designating the visible form-elements of living matter. To the "molecules" of a plastid, *i. e.*, to the smallest conceivable particles of which the plastid as such consists, I have given, primarily for the sake of brevity and convenience, the name "plastidules," a name that has found favor with most writers on the subject.

Now, since not only the peculiarities of the immediate parents, but also those of anterior ancestors, whether these peculiarities have appeared in the parents or not, may be hereditarily transmitted, and since whatever is transmitted must be contained in either the ovum or the sperm, it is certain that these two constituents of the germ contain plastidules or molecules of living-matter to which are attached all these peculiarities. I assume, and this assumption with the qualifications that follow constitutes the plastidule hypothesis, that the germ of each derivative living being consists of plastidules of its whole ancestry.

Everybody must admit that just as the germ, or fecundated ovum, from which a child proceeds, consists of matter wholly derived from the bodies of its parents, so the germs from which these parents sprung existed in the bodies of their parents. Now, if we assume that some of the particles of matter from the grandparents have remained in the parental bodies until the procreation of the child, then there may be contained in the germ of the grandchild actual plastidules of the grandparents. For those who can more readily conceive the idea of force or quality being transmitted than matter, I may add that the term plastidule refers quite as much to a centre or bundle of force as to matter.

Against the idea that plastidules of the grandparents would be present in the developed body of the parent, or that they would be preserved until the procreative act, the objection might be urged that the constant change of tissue in the body, the decay and death and excretion, would make the preservation of these particles of matter impossibe. To such an objection, the reply is that the material of the body breaks down and is eliminated only through use, and that the use through which the special particles

under consideration are removed from the body is only the generative act,—so that it may well be that they are conserved until used for generation. Besides, it suffices to assume that the transmitted plastidules are not the identical ones of the grandparents, but molecules of the parent that have, by assimilative nutrition and growth, become, in all properties and capacities, like them, and for our argument may be, therefore, considered as such.

Not only plastidules of the grandparents are assumed to be contained in the germ of the child, but also plastidules of the great-grandparent, and a long line of ancestors; and the difference between the germs of children of different parents consists in the very fact that each contains the plastidules (molecules or bundles of qualities or of force) of its own individual line of ancestors. The further back we can trace the genealogy of a child, the more complicated becomes the representation of the genetic constitution of its germ. How many generations there may have been and passed away between the birth of the child of to-day and the time of its ancestors in the far past, or since the existence of the first human parents! Let us take the primitive pair—Adam and Eve: their children came from germs which were wholly derived from their bodies. The germs of the children of these children contained, mixed with the modified plastidules of their immediate progenitors, some of the plastidules of the first parental pair; and so on for succeeding generations. The farther removed from the first ancestor, the smaller, of course, is the quantity of his share in the constitution of the germ of the progeny. To express the idea arithmetically: in each succeeding generation, the numerator remaining the same, the denominator of the fraction of the set of plastidules from a particular ancestor increases.

Plastidules, though inconceivably small, nevertheless have actual dimensions, and it may well be conceived that after a certain vast number of generations the plastidules of a particular ancestor may exist very sparsely, or even not at all, in the germ of the progeny. This does not prevent, however, the influence of these ancestral plastidules persisting for a long time, since the plastidules of the succeeding ancestors still contain them more or less mixed or modified. There may be, however, circumstances of which we are as yet ignorant, which may cause the exhaustion or diminution, or lessen the influence, of any particular plastidules,

and these possibilities become a qualification of the proposition that the germ of every derivative living being contains plastidules of *all* its ancestors.

I have named this explanation of the phenomena of inheritance, the hypothesis of regeneration; because, according to it, the ancestors are, to a certain extent, bodily, mentally, and in every other respect, born again in their progeny. It may be called also, the hypothesis of the preservation of organic force, or of the preservation of organic molecules, because according to it, certain plastidules are, though not forever, for a long time, preserved and transmitted from generation to generation. To designate the idea more simply I use the term Plastidule Hypothesis.

MONOGRAPH ON JADE, ILLUSTRATED WITH FINE SPECIMENS IN ALL THE DIFFERENT VARIETIES. By ERMINNIE A. SMITH, of Jersey City, N. J.

[ABSTRACT.]

THE close relationship between the United States and China, effected by our great Pacific Railways, has brought into this country many beautifully carved specimens of the heretofore almost unknown and unseen substance jade.

This term has been applied to so many substances, related perhaps in some of their physical characteristics yet differing widely in chemical composition, that much confusion has arisen regarding their nomenclature. If so vague a term must be used why may not amateurs retain for their finely carved specimens the beautiful appellation "*Yu*" of the Chinese, which would suggest to those familiar with that language and literature many of the tender and endearing epithets derived from the name of the substance, which among eastern nations is not only a badge of sovereignty and symbol of every virtue, but an object of veneration, often of worship?

An analysis by Damour of the white oriental jade from China, gives silica 57.60; magnesia 25.61; ferrous oxide .66; lime 12.68; alumina .25; water 2.74; and a specific gravity of 2.97.

The Oriental and Oceanic jades of New Zealand do not differ very widely in their chemical composition from the Oriental of China, but the specific gravity of the New Zealand Oriental is 3.015, and of the Oceanic 3.18, while the so-called dark green

jade of China gives on analysis, silica 59.62; magnesia 1.15; ferrous oxide 1.56; lime 2.68; soda 12.93; alumina 22.58; and its specific gravity is 3.34.

This great difference in composition caused Damour to regard it as a distinct mineral which he termed jadeite. Being much harder than the Oriental jade its workmanship is much more difficult and the whole life of many a patient Chinese is spent in the excavation of a single *chef d'œuvre* which is esteemed almost priceless.

The mask on exhibition is of this material, its specific gravity being 3.33. This interesting archæological specimen was exhumed from an Aztec tomb in Mexico and is authenticated by the Spanish Consul of that city, although the "crying baby face" might argue an Eastern origin. There is, however, a somewhat similar face in quartzite to be seen in the Peabody Museum which was also found in Mexico. As jade is not now found either in Mexico or Central America, the question arises, did the ancient Mexicans have some early communication with the Old World, for we know that jade ranked as their first jewel and indicated the "blue blood" of the wearer?

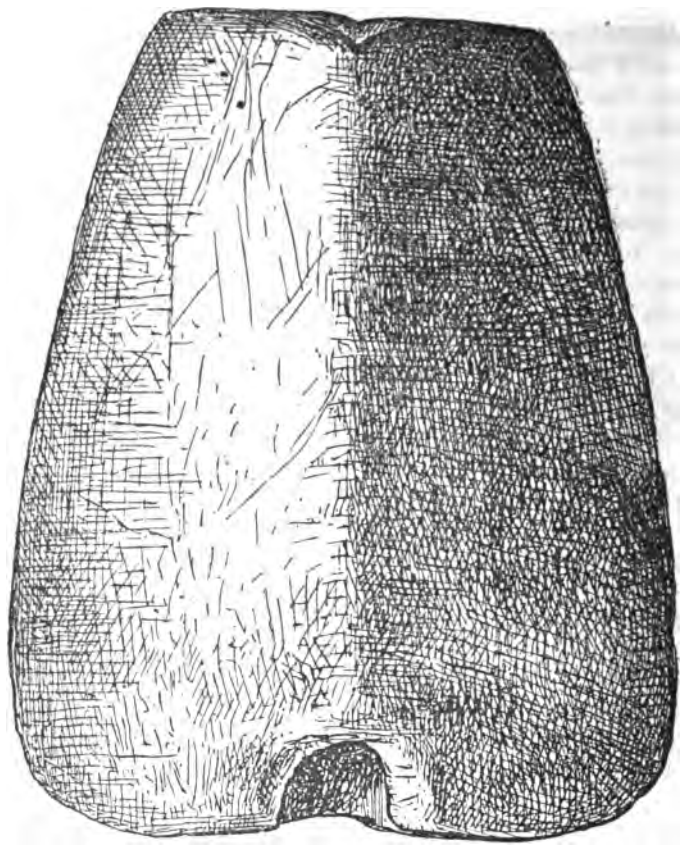
Häuy describes another variety of this substance as *jade Tenace.* This is still harder than jadeite with a specific gravity of 3.4 and is now termed saussurite. Many of the Swiss celts are made of this mineral which is found in abundance around the lake of Geneva. But many of these celts are also of the true Jade as are these upon exhibition, and it now remains for archæologists to decide whether this material was brought by those settlers from their early abodes or obtained by barter, as no jade or jadeite has been found in Europe. The Merai and Liki on exhibition are from New Zealand. Similar varieties have been described in "Wood's History of New Zealand." The ear-ring exhibited is of the hornblendic variety of Oceanic Jade.

The specific gravity is the only scientific means of determining the variety of a carved specimen in this substance, but the practised eye of a connoisseur can easily detect an imposture like clouded chalcedony, glass paste, saponite, serpentine, green jasper and Amazon stone, which are sometimes palmed off upon the unscientific collector, under the very inclusive term jade.

Description of a Polished Stone Implement found in Monkton, Vermont. By John M. Currier, of Castleton, Vermont.

[ABSTRACT.]

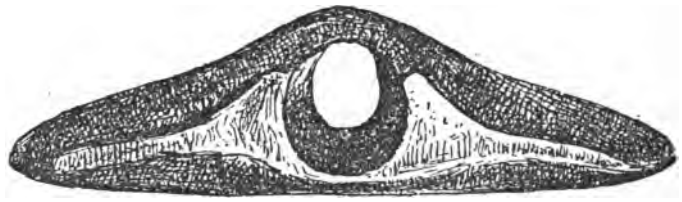
The specimen from which the accompanying cut was taken was ploughed up by Davis Dalton, in 1875, a few rods west of Monkton



View of convex surface, ½.

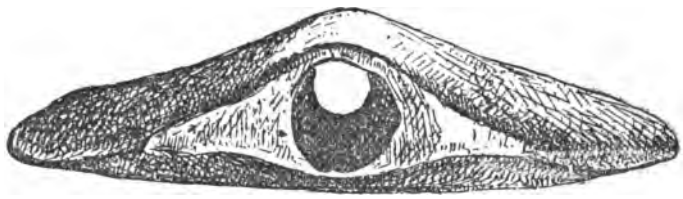
pond, in the town of Monkton, Vermont. It soon after went into the possession of Dr. O. L. Nimlett of that town, who kindly presented it to the writer. Many stone implements have been found

in that vicinity. The three figures give a better idea of the shape of the implement than can be given in words. Its length is four and one-fourth inches; width at the larger end three and one-



View of large end, ¼.

half inches, at the smaller end two and one-eighth inches; greatest thickness at the larger end, one inch, at the smaller end seven-eighths of an inch. One surface is nearly plain, being slightly



View of small end, ¼.

rounded off at the edges. The opposite surface is bevelled off to the right and left from the longitudinal mesial line to either edge, which is rounded off to meet the rounded edges of the plain surface. The thickness of either side is about one-fourth of an inch.

Lengthwise, through the centre, a hole has been drilled, five-eighths of an inch in diameter at one end, and a trifle smaller at the other. The hole is nearly round, bulging a little on three sides. Circular drill marks are perceptible the entire length.

The specimen is smoothly polished though some coarse marks remain. Scratches from use appear on it; also scratches that may have been produced by the plough or harrow. One side of the hole at the larger end has been broken out, probably by accident in use.

The material from which this specimen was made is a soft,

green, argillaceous slate. One portion of the stone is of a light green shade, the other of a dark green shade. The line of union between the two shades passes obliquely through the specimen.

Many similar perforated implements have been described from other parts of the country but as this is the first I have seen from Vermont, I have thought it worthy of this brief notice.

NOTES ON THE ARCHÆOLOGY OF THE CHAMPLAIN VALLEY. By GEORGE H. PERKINS, of Burlington, Vermont.

IN the St. Louis volume of the "Proceedings" there is an abstract of certain general remarks made by the author upon the Archæology of Vermont. The design of the present paper, which was illustrated when read by both drawings and specimens, is, without repeating the facts given in the former paper, to present a more complete, though necessarily very imperfect, account of some of the main features thus far discovered in the Archæology, not only of Vermont, but of the entire region bordering Lake Champlain.

The Champlain Valley, although by its natural characteristics eminently fitted for occupation by savage tribes, and very inviting in many portions to those that wished to form permanent settlements, does not afford thus far, indications that its borders have been thus occupied at least for several hundreds of years. Possibly —we may even say probably,—centuries before the coming of the white man, the eastern shore, which is most fertile and far less rugged and wild than much of the western, supported a considerable population. There are indications of this which we cannot delay to mention, but there is no absolute proof of it. Champlain found the shores of his lake uninhabited two hundred and seventy years ago, and the reason which his savage friends assigned was doubtless a true one: they told him that because of wars between the Algonkins and the Iroquois, the large islands and shores which had once been inhabited were so no longer. And to-day the archæologist finds his treasures not in heaps, nor thickly strewn

over small areas, but scattered singly or at most in very small numbers here and there all over the region. Of course some localities are richer than others,—here, fragments of pottery may occur in considerable quantity, there, an arrow-maker stopped long enough to cover the ground with chips among which finished specimens of his work may be found, but such quantities of stone implements as have been found crowded together in a small space in some parts of the country never occur in the Champlain valley. Aside from the discoveries at Swanton, Vt., fully described in the Portland volume of the "Proceedings" and those near Plattsburgh, N. Y., to be specially mentioned hereafter, I know of no very prolific locality, near the lake. However, as both of these "finds" remained wholly concealed beneath the sand in which the specimens were buried until the removal of the forest growth on the surface permitted the wind to blow off the surface sand and thus disclose the hidden treasure, we may hope that in future yet other similar discoveries may be made. At the St. Louis meeting I stated that there was no evidence that the early inhabitants of the Champlain valley cultivated the ground, but soon after my return several undoubted agricultural implements came into my hands, and I have heard of a number of others in various local collections. Still these implements are not common and as objects of such size and strength would necessarily be more easily preserved than those that were smaller and more fragile, their scarcity would show that agricultural labor was not extensively carried on; and as such implements as have been found were obtained mostly on the eastern side of the Green Mountains, it would follow that the Algonkin tribes living there were more inclined to till the soil than the Iroquois of the shores of Champlain. Still we can not reason with much certainty from such meagre data as we now possess. None of the agricultural implements that I have seen equal in regularity of form and elegance of finish the best implements of this class from the West, nor are they so large. In form, they are ovate, lanceolate, leaf-shaped, or some modification of these forms, and usually inequilateral. All are more or less narrowed to a blunt point at one end. They are strong, though not always clumsy. They vary from five to ten inches in length and are about half as wide. I should judge that most, if not all, were used as spades, though I have heard of some which were called hoes. It is possible that some of the objects classed

as celts were used as spades or hoes, for among the Vermont specimens there are some which are of a character rendering them more suitable, one would suppose, for cultivating the ground than for use as axes or even chisels. If we study the agricultural implements of many modern tribes of uncivilized people we find among them some very much like some of the ancient "celts" and I am inclined to believe that many implements classed in our collections as "celts," "ungrooved axes," and the like, were really spades or hoes. If this be true, agricultural implements may be more common in some localities than we have supposed.

The Champlain valley furnishes us with specimens of most of the ordinary forms of axes. As would be expected by far the most common is the "celt" or ungrooved axe, and some of these are quite large, of very fine material and with polished surfaces. Others of coarser material are more rudely made. In some the edge is curved, in others straight. So great a diversity of form is seen in this class of implements that it is difficult to resist the belief that they were not all axes, but served a variety of uses, or perhaps the same implement served, as occasion required, different purposes. A few specimens have been found which form, in some sort, a connecting link between ungrooved and grooved axes. These are grooved only on the narrow sides, but not across the broad sides, so that they are notched rather than grooved. These notched axes are both large and small and usually rude. Some fine specimens of grooved axes have been found, but they are far more rare than in many portions of the country. The largest that I have seen is nine inches long and four and a half wide, but most are much smaller. One unique specimen which may be called an axe was found near the Connecticut river in the southern part of the state. This specimen, which is in the form of a letter L, with an edge at each end, is figured and described in another place.[1] It quite closely resembles an English specimen figured by Evans[2] but is much larger, being seven and a half inches long. Hatchets or tomahawks are not very uncommon. Some are of greenstone, slate, etc., and of course ground into shape, but most are of flint, hornstone or quartzite, flaked. I find it difficult in some cases to determine whether the specimen was intended for a large knife or a hatchet. Some of the hatchets are very sharp and well formed

[1] Am. Naturalist, Vol. XIII, p. 738, pl. II, fig. 6.
[2] Ancient Stone Implements, p. 124, fig. 82.

and must have made very effective implements. In the museum of the University of Vermont there are three specimens of a form such as would ordinarily be called "pestles," but it is more than doubtful whether they were intended for such a use. I think that they were made either for clubs or batôns. One end is carved, rudely indeed, but not indistinctly, in the form of the head of an animal. The form is cylindrical; the end not carved is rounded and shows no sign of use. The largest is twenty-seven inches long and weighs six pounds.[3] Other specimens of the "pestle" order seem to have been used as rollers, as they are very round and smooth at the ends as if worn by rubbing against the hand. Specimens of this sort are usually very well made, of hard material, largest in the middle and tapering towards each end. Other specimens could not well have been used for any other purpose than pounding as they are square with rounded ends. One of these is a foot and a half long and three inches square. Some of the specimens are rounded on two sides and flat on the other two; others are club shaped. The short conical pounding stones found in the West never occur in the Champlain region. Mortars are more rare than would be supposed. Those that I have seen are rather rudely made and quite shallow. Pipes are among the rarest specimens in our collections, as well as the most elegant. They are very rarely of terra cotta, more often of stone. Two have been found of the former material, of a trumpet form, very nicely made and finished. One of these is figured in the article in the Naturalist already referred to, as is also one of the stone pipes. A pipe of coarser material but of very regular form was found last fall near Plattsburgh, N. Y. This is of modern form, the stem being at a right angle with the bowl, and one of the stone pipes which was found near Burlington is of the same general form. All of the other stone pipes are cylindrical or urn-shaped and are very well made and finely polished, so that although far from being as elaborate and elegant as the finer specimens from the mounds, they are nevertheless as well finished, and made with equal care. None of them are carved to imitate any animal form, unless it be in one case where the margin of the bowl is prolonged on one side to form what may have been designed for the beak of a bird.

Knives are found in great number and variety in all parts of the Champlain valley. On the Vermont side only chipped or flaked

[3] For fuller description of these see Am. Nat., Vol. XIII, p. 739, pl. II, fig. 1.

specimens have been found, while on the opposite side of the lake both flaked and ground knives occur. The flaked knives vary almost indefinitely, both in form and degree of elegance. Some are rude in the centre but carefully finished about the edge. Oval forms are perhaps more common than others, but lanceolate knives are also abundant. Some are long, narrow and dirk-shaped, others short and wide. Forms much like a modern knife-blade are not uncommon, with an edge along the curved side only, the straight side being often quite thick. Stemmed knives are as common as those without, and of as great variety in form. Some of them are very carefully chipped and have sharp edges. It is stated above that only chipped knives,—of course made of quartzite, flint, or some silicious stone,—are found on the eastern side of Lake Champlain; but if the peculiar slate specimens with stems bearing a series of small notches on each side, which have been described in former articles,[4] are to be regarded as knives, this statement must be modified accordingly. On the New York side, however, besides flint knives similar to those found in Vermont, slate knives of excellent workmanship have been found. One of these is very much like one figured in "Stone Age in New Jersey"[5] except that it has no thickening along the back. It is a little larger than Dr. Abbott's specimen. It is exceedingly well made, of hard slate, the sides not polished, but smooth, and striated by the material used in grinding it. It is a little more than six inches long, and in the widest part, two inches wide. As one end is broken, the entire length was originally a little more than that given. The thickness at the back is a little less than one-fifth of an inch. Another beautiful specimen,—though a considerable fragment is missing from each end,—is shaped more like a modern chopping-knife. The material is drab talcose slate, and the surface is polished. Along the back is a thickened ridge like that in Dr. Abbott's figure, and of about the same width. The blade is flat, and wider than in the specimen alluded to, and the edge is more convex. The length is four and six-tenths inches, and the width, where greatest, two and three-fourths inches. Both of these unusually fine specimens are in the collection of Dr. Kellogg of Plattsburgh, near which place they were found.

About a mile north of this town there is a very interesting lo-

[4] Am. Naturalist, vol. V, p. 16, fig. 5 and vol. XIII, p. 741, fig. 7.
[5] Smithsonian Report, 1875, p. 303, fig. 114.

cality for archæological investigation, one of the most so in the Champlain valley. Low sand-ridges run along the head of Cumberland bay, sometimes approaching within a few rods of the shore and nowhere being far from it. These ridges were covered with trees, chiefly pines, but lately some of these trees have been removed, thus leaving the surface exposed to the force of the wind, which has swept off the light soil and excavated large gaps through the ridges, some of them twenty or thirty, or even more, feet deep. In the fall of 1878, Dr. Kellogg discovered fragments of pottery in the places exposed by the wind, and soon after, in his company, I visited the place and have since repeatedly examined it. When I first explored the place there were several wide cuts, and over the sand at the bottom and along the sides, were great numbers of bits of pottery of all sizes, from those no larger than a pea, to those as large as one's hand, and often pieces lying adjacent could be fitted together so as to form quite a large portion of a jar. In some places the sand was very thickly strewn with these fragments, in others they were more sparingly scattered. As those specimens first obtained were evidently not *in situ*, but fallen from their original location, it was not possible to ascertain the depth below the surface of the deposit, but subsequent investigations have shown that it varies from not more than three feet to very much more. Dr. Kellogg and myself dug from beneath the roots of a pine some large fragments firmly embedded in the sand, which, very evidently, had not been disturbed for a long time, and these were not more than three or four feet beneath the present surface, but we have also dug specimens from twice that depth. The sand is now blown off from quite large areas, several rods wide and long, and over these areas are found, always at a considerable depth below the present surface, deposits of charcoal and ashes several inches thick. Most of the specimens have been found above this layer, but by no means all. As the material of the ridges below the layer of vegetable mould on the surface, and indeed of the entire region about it, is pure yellow sand, without, in many portions even a pebble, any foreign body is quite conspicuous, and on this account certain heaps and clusters of large stones, scattered here and there, at once attract attention. These stones are of all sorts, and were evidently obtained from some deposit of boulder-drift, as they possess the usual characters of the material of

such deposits. They are from three or four inches in diameter to more than twice this size. Most of them showed evident indications of having been heated. There were twelve of these clusters of stones visible, each covering a space of perhaps six feet square. Usually they were isolated from each other, but in one or two instances two were near each other. From the nature of the case their exact depth below the surface could not be precisely determined, and if it had been, the determination would have been of little value, for the mobile character of the soil renders it almost certain that the surface has changed many times since the stones were piled upon it. However, all of them are several feet below the present surface. From the character of these groups of stones and that of their surroundings, I believe that they, some of them at least, constituted kilns for the burning of the pottery which is now strewn in fragments about them. Some may very likely have formed fire-places; for, as will be seen, there are evidences of a more or less permanent encampment or settlement at this place. It would seem to be conclusive proof that pottery was burned in this place, that we find irregular masses of burned clay, or rather of the same material as that of which the jars were made, which can only be regarded as refuse left in the manufacture of the jars. All the materials needed in this manufacture are found near by.

As has been stated, when first visited, the sand was in many places thickly strewn with pottery, but as excavations by the wind have not kept pace with the labors of collectors, it is not easy at present for a person unfamiliar with the locality to obtain many specimens. Dr. Kellogg has with indefatigable perseverance explored the locality, and, as the result of his labors, now possesses a large collection of not only pottery but stone implements. In all he has several bushels of fragments; other collectors have lesser quantities, and the locality is by no means exhausted. Indeed, I think it by no means unlikely that more yet remains in the sand banks than has been taken from them. Not a single entire jar has been found and the reason is not far to seek, for the sand at any distance below the surface is always damp, so of course is the embedded pottery, and it is with very great difficulty that even a large fragment can be gotten out entire. So little tenacity have some of the pieces that when first obtained they may break from their own weight, if held by one side. The

fact that this damp sand is usually packed very firmly, increases the difficulty. While no complete specimens have been found, masses of fragments have been obtained, which when fitted together, so far produced the entire jar, that its form and size could be determined. In the case of the rim this is more often true than of the rest of a jar, for the greater strength of this portion makes it more likely to be preserved than other portions. Dr. Kellogg has suggested, what is very likely true, that many of the pieces of pottery may be those of articles destroyed in the process of manufacture, but as he has called my attention to several pieces which have still adhering to them what appears to be the charred remains of food cooked in them, it is doubtless true that many were not only made, but used on the spot, for household purposes. The facts mentioned are sufficient, I think, to account for the absence of whole articles of pottery. In color and general character this pottery resembles that from other localities in the Champlain Valley and elsewhere. The color varies from light clay color, through various shades of red, drab and brown, to black, the darker shades predominating and specimens entirely black are not uncommon. The quality is very different in different specimens. In some cases the paste was composed of so finely ground materials that they are indistinguishable, while in others we find conspicuous bits of quartz or feldspar mixed with the finer paste. All received a coating of fine paste consisting chiefly of clay over both the outside and inside, giving a smooth finish to the surfaces even when coarse materials were used for the main mass of the article. As to the size of most of the jars nothing definite can be said, though fragments of many of them are sufficiently large to give at least some idea, and in some cases a pretty accurate one, of the size of the article to which they belonged. Some of them were undoubtedly large and others smaller. The rims of a number of them are so nearly complete that we can readily measure their diameter and we find this to be from five to fifteen inches, but probably seven or eight inches was the most common size of the opening, and it is also probable that the usual globular form was that of the lower portion of all of them. The upper part, however, shows more variety. One class of jars were globular, or flask-shaped, wholly without ornament except just about the rim which is circular, not recurved or flaring, though having a narrow lip. Jars of this sort are mostly small and often quite thick. Another form is similar, but the rim is

much recurved, so much so in some cases as to form a wide horizontal surface, which is covered with indented lines and figures and these do not always have a circular opening but in some it is square, or more rarely pentagonal, being compressed below to form a neck, below which the form is globular. The largest jars are mostly of this sort, and some of them are very thick and heavy. Some of these are ornamented profusely over the upper third or half, and rarely the entire outer surface is ornamented. In this case the lower globular portion is impressed with a sort of willow-basket figure, as if moulded in a basket of woven rushes or grass. In some specimens the ornamentation is not confined to the outside, but extends over the rim down the inside sometimes for several inches. The inside decoration does not exhibit so great a variety in pattern as does that of the exterior and is usually made up of horizontal rows of dots or linear figures. Aside from this, some of the jars were covered on the inside with shallow, horizontal grooves, but most are smooth inside. A few specimens have the rim very neatly scalloped, others are denticulated, but such are rare. The decoration of the outside is difficult to describe, it embraces so great a variety of patterns. Probably not less than five hundred different designs exist in the fragments already collected in this one locality. In looking over Dr. Kellogg's collection I counted over three hundred fragments of rims, each differing from all the rest in style of ornament. Many other pieces different from all of these are in his collection and my own. Some of the combinations of lines, dots, denticulated, key-shaped, and other figures, are very elaborate and pretty. In some cases stamps were undoubedly used, as denticulated lines two or three inches long are to be seen, which are repeated, and the end of one line of denticulations overlaps that of another, or is perhaps separated by a small space from it. Rows of depressions made by some blunt pointed bone or other instrument are common.

Bands an inch or so wide made up of vertical rows of small dots or other figures alternate with continuous lines. Rows of fine scallops, waved lines, parallel lines of various widths, arranged horizontally, vertically, obliquely, or crossing each other to form lozenge-shaped spaces, are not uncommon. Circles, semicircles, squares and triangles are common, of various sizes, and many other forms not easily described. Some of these figures are bold and deeply stamped but many are very fine and delicate. I have not

seen from any locality more exquisite specimens of stamped earthenware than some of this.

On smooth, even surfaces, multitudes of fine figures thickly impressed form a very elegant decoration. In many specimens the impressions completely cover the surface, though specimens also occur in which the figures are more sparingly used. Not only at the locality we have described, but in other places farther from the lake, similar, though smaller, deposits of pottery have been discovered. Aside from the evidences already mentioned, there are other indications of a somewhat extended occupation of this locality. Flint chips are found together with entire spear and arrow points, also hammer stones, axes, grooved and ungrooved, pestles, scrapers, disks of quartz, cylindrical stone beads and one of coral, have been found with the pottery. Human bones in an advanced stage of decomposition have also been found by Dr. Kellogg. He has also found not far away considerable quantities of the long bones of deer, split longitudinally, and also a very interesting bone spear-head very nicely made. This specimen, which is especially interesting because it is the only bone implement hitherto found in the Champlain valley, is barbed on each side with five rounded points, which, as they have some appearance of being worn, may have been originally sharp. The surface is convex and smoothly finished — almost polished. The outline is regular and every part of the implement shows skilful workmanship. The base is broken so that it may have been longer than now. Its present length is a little less than four inches and it is about three-fourths of an inch wide at the base, from which it tapers but very little until the anterior barbs are reached, from which the sides curve towards each other to form a rather blunt point. The resemblance of this specimen to some of the bone spear-heads from European localities is very striking. As to the age of the deposit of pottery and the associated stone objects we are left almost as much in the dark, as in regard to that of the rest of our Champlain valley specimens. The location of the place where the kilns are found is such as to force us to believe that they were not, in all probability, used later than the advent of Champlain. As we have seen, there are strong grounds for believing that we have in this manufactory of pottery not a temporary stopping place but a settlement of considerable duration. The very nature of the articles manufactured indicates this,— a war

or hunting party would not establish an extensive pottery, nor would any party not making the place one of residence. But Champlain tells us in his narrative that he sailed southward through the lake from Canada and saw no settlement, nor even,—we are left to infer,—a wandering band of the Iroquois, who held the region about the lake, until he reached a point far south of that with which we are concerned. He states moreover that he sailed along the western shore of the lake. Had there at that time existed a settlement at the head of Cumberland bay so exposed to view from the lake as this must have been, Champlain, or at any rate his keen-eyed Algonkin companions, could scarcely have failed to discover it or indeed to have known of it long before. Nor is there any probability that, at any time subsequent to Champlain's voyage in 1609, any settlement could have existed at this place; in fact it seems certain that there did not. If this be true, then we are forced to believe that the locality was occupied either by Iroquois, or by some antecedent people, before the hostilities began which forced those living in the neighborhood of the lake to seek safer sites for their habitations; and how long ago that was, we can only guess.

If we compare the collections of objects found upon the east and west shores of Lake Champlain, we find that they are substantially identical, and that undoubtedly the greater part of them represent the work of the same people. Naturally, specimens of various kinds have been found on each side of the lake which can not be duplicated on the other, but the larger and more complete the collections become, the more clearly does their similarity appear. In both the stone implements and the pottery, this similarity appears. In the latter, however, we find a much greater variety in the principal locality on the New York shore to which we have given attention, than is found in Vermont pottery, but many of the designs are identical and the general style is the same in both, as may be seen, I think, by referring to an account of Vermont pottery already published.[6]

On both sides of the lake we find many objects very much like those of similar character from the mounds; especially is this true of gorgets and other objects used, presumably, for ornament, also of copper implements most of which are identical in form with some of those from the mounds. From this fact it would seem

[6] Proc. A. A. A. S., Vol. XXV, p. 325. Also Am. Naturalist, Vol. V, p. 14, figs. 1 and 2.

probable that the copper implements used in the east were imported as such from the West rather than made by the tribes who finally owned them. In the stone implements, however, it was neither the object nor its material that was imported but only the pattern; for the material is, I think, in all cases, such as is found in this region and is not found elsewhere; as, for example, the common red and purple roofing slates which were used for "two-hole" stones and other amulets, as well as for "boat-stones" and "birdshead" stones.

In the collections of the more ordinary stone implements, as gouges, axes, knives, spear, lance, and arrow-points, etc., we find local material chiefly used. On this account, brilliancy of color is less often seen in collections from the Champlain valley than in those from the south or west. Gray, bluish-white, drab or greenish shades prevail, and though many of the specimens by no means lack beauty, they are not often showy.

TITLES OF OTHER PAPERS READ IN SUBSECTION E.

THE ETHNOLOGY OF THE ISLANDS OF THE INDIAN AND PACIFIC OCEANS; ILLUSTRATED BY A LARGE COLORED MAP. By ALBERT S. BICKMORE, of New York, N. Y.

ARCHÆOLOGICAL NOTES FROM JAPAN. By E. S. MORSE, of Salem, Mass.

ON SOME LARGE AND REMARKABLE STONE IMPLEMENTS OF THE SOUTHERN MOUNDBUILDERS. By F. W. PUTNAM, of Cambridge, Mass.

ON THE POTTERY OF THE SOUTHERN MOUNDBUILDERS. By F. W. PUTNAM, of Cambridge, Mass.

SUPERSTITIONS OF THE ANCIENT INHABITANTS OF THE MISSISSIPPI VALLEY RELATIVE TO THE RABBIT. By J. G. HENDERSON, of Winchester, Ill.

SUPERSTITIONS OF THE ANCIENT INHABITANTS OF THE MISSISSIPPI VALLEY RELATIVE TO THE OWL. By J. G. HENDERSON, of Winchester, Ill.

SUPERSTITIONS OF THE ANCIENT INHABITANTS OF THE MISSISSIPPI VALLEY RELATIVE TO THUNDER. By J. G. HENDERSON, of Winchester, Ill.

SUPERSTITIONS OF THE ANCIENT INHABITANTS OF THE MISSISSIPPI VALLEY RELATIVE TO SERPENTS. By J. G. HENDERSON, of Winchester, Ill.

LAKE ERIE AND THE ERIES. By J. G. HENDERSON, of Winchester, Ill.

EXHIBITION OF ARCHÆOLOGICAL OBJECTS. By S. S. HALDEMAN, of Chickies, Pa.

EXECUTIVE PROCEEDINGS.

REPORT OF THE GENERAL SECRETARY.

Wednesday, August 27, 1879. The Association assembled in the Town Hall, Saratoga, N. Y, and was called to order at 10.30 A. M., by Professor O. C. MARSH, the retiring President, who introduced the President elect, Professor GEORGE F. BARKER, of Philadelphia.

President BARKER accepted the chair in the following words:—

Fellow members of the American Association for the Advancement of Science:—

I trust I am not insensible to the high honor which you have conferred upon me by electing me to the office of President. I cannot but regard it as a coincidence as pleasant as it is striking, that precisely twenty years ago I joined the Association and enrolled my name among its list of members. Looking back now to that Springfield meeting, presided over with so much dignity by one whom the touch of time has spared to remain among us, Professor Stephen Alexander of Princeton, there pass before me in stately procession the eminent men who gave tone and character to that meeting and worthily upheld the name of American Science. Alas, that so many of them have passed away leaving us to bear the burdens which they carried with so much ease. Standing now upon the threshold of another meeting and looking back upon the past of this Association, glorious with the names of men distinguished in every branch of science, I feel proud that I am permitted to occupy this chair. But on the other hand, when I think of the illustrious men who have stood where I stand and have directed your deliberations, I feel very humble. It is the sight of so many of these Past Presidents here upon the platform with me that encourages me to undertake this duty, and fixes in me the desire to hand onward to my successor the office which Professor Marsh has just now placed in my hands undimmed in the lustre of its fame and untarnished in its reputation. Again I thank you for this honor and pledge myself to use my best endeavors to serve the Association well and to justify the selection which you have made.

President BARKER then called upon REV. PETER STRYKER, D. D., to open the meeting with prayer. After the invocation an Address of Welcome was delivered by Dr. R. C. MCEWEN, Chairman of the Local Committee, who spoke as follows:—

MR. PRESIDENT AND MEMBERS OF THE ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

It is said, there is nothing new under the sun. And we do not propose to question the abstract truth of the proposition. It may be that the physical laws which govern the world have ever been unchanged, and the

mutations that are laid before us are only recognitions on our part of new applications of principle. It may be that we have discovered nothing new in man's relation to his fellow man, and the laws which govern him as a social being. Yet overshadowed by the presence of the scientific intellect of the day, and under the shadow of a negative statement as to the existence of novelty under the sun, I rise in behalf of those I represent to extend to the workers in the fields of science, a cordial welcome to a spot on God's footstool, that is reputed the resort of the votaries of pleasure.

There were germs of philosophic truth planted amid the ignorance and superstition of earlier days, but the golden harvest of the present is the rich reward of inductive research; and it can no longer be said of science, that she has done but little to increase the power, diminish the suffering, or augment the happiness of mankind. Her language may not often be heard here in our midst, yet the rustling of the silk, or the setting of the diamond might have been less valued by the fashionable world, but that science had added lustre to the fabric, and artistic taste to the fretwork that holds the glittering jewel. Her labors may be wanting in the sentimental, and association may picture the scientist, as the sum and substance of ponderous fact, mingled with the dry and uninteresting details of investigation. But the wonders in heaven above, and earth beneath disclosed by science in her search; our daily walk amid the poetry of her teachings, and surrounded by the material developments that are the work of her hands, raise life beyond the plane of animal existence, and round out the fulness and completeness of man as an intellectual being. The eye of science has penetrated the depths of earth, and interprets the inscriptions imprinted by nature in ages past. Chemistry is the key that has unlocked many a mystery, and in the lines of a solar spectrum science is revealing the secrets of distant worlds. The Copernican system was heretical in days of old, but the telescope triumphantly proved its truth, and its deductions are a guide to the mariner on the pathless ocean, and a bond through commercial intercourse, between the nations of the earth. It was a spark from the clouds, that travelled the hempen string of a flying kite. "What hath God wrought," the first message that winged its flight over the electric wire, was the response of science in after years; and the subtle messenger flashes over earth and through ocean, strengthening the ties of peace and amity, and promoting the unity of national interests. Science revises the laws of acoustics, and the wires of telephonic communication lengthen and multiply. Articulate sound flies to and fro, as enquiry is made and answer returned at distant terminal points, and the perfecting of such a means of communication is one of the problems of the day, involving questions for future consideration, in the light of political economy.

Discovery and invention go hand in hand, art is stimulated, intelligence diffused, and the developments of the present age are the foundations of a structure for the future whose portals but few of us may enter, and of the wonders that shall dwell within, we may have but a limited conception.

The realities of the present may have been the dreams of the past, and the Saratoga of to-day may be the crystallization of many a former prediction. Not many generations since, a party of settlers wended their way through this wooded region, seeking under the rays of a summer sun, and in the silence of nature's solitude, the same healing water now obtained by the multitude who come hither, whirled through space by the strides of science, and subjected to a hotel tariff of elastic proportions. The footfall in the wilderness is now the rush of thousands in the advance of civilization, and the restorative draught of 1767, that bubbled from the conical top of the High Rock Spring, and relieved the infirmities of Sir William Johnson, has developed a wealth of remedial resource, that has made this spot famous throughout the wide world.

The member from the Continental Congress, who in 1792 discovered the small stream issuing from the creviced rock on the borders of a natural water course in this then wild region, could not foretell the future of his research. The name of Congress Spring was given his discovery in view of the superior quality of the newly found water, and in honor of the august body of which he was a member. Its virtues may have been less fluctuating than those of the representative body from which it derives its name, but its fame has been identified with every progressive step in the history of our village. Art has subdued the ruggedness of nature and the fairy scene of its present surroundings forms one of the most attractive spots within our borders.

Time will allow me to make but a passing allusion to the historic charms that centre here, and the important position given to this locality in the thrilling history of the Revolution, and I can only refer you, as I point to the gifts of nature around us, to the gift that was here bequeathed by the patriot arm, as the heritage we now enjoy, and the national blessing we strive to maintain.

Natural mineral waters, whose therapeutic value, proper and judicious use has established, and whose restorative qualities none can doubt, have attracted thither the seeker after health. Palatial hotels famed far and wide for the elegance of their appointments, surpassed by no similar structures in the land, and abounding in comfort for the outer man, and the choicest of supply for the inner, invite the traveller to rest. Wide and shaded streets, attractive drives, elegant and tasty dwellings, and a pure, bracing and invigorating air, make up a sum of attractions such as few places on the continent can offer. The bankers of sense and the butterflies of folly enjoy the summer hours as taste or inclination may dictate, and drink at the healing fountains, to invigorate the body or remove the pangs of imprudent indulgence. A varied nationality; wealth beauty and refinement; the representatives of every grade of social distinction and every class of worldly occupation and interest, form the cosmopolitan character of our summer population.

With natural and social advantages unsurpassed, with our increased facilities for entertainment, and the varied comforts the hand of man can create and bestow, Saratoga is becoming a centre for holding assemblies

similar to your own. The representatives of the political interests of the country, the exponents of various forms of religious belief, those who seek to promote the highest interests of man as a social being, specialists in various branches of scientific pursuit, the guardians of finance, the powers of the press, and the able judiciary of the state, have met in our midst and been entertained. And we are glad to-day to extend a cordial welcome to these representatives of progressive knowledge, who in congress assemble to promote the advance of science, and give to research in her various departments a wider scope, and more zealous purpose.

And now, sir, in behalf of the local committee, who have sought, as far as possible to provide for your requirements, and in behalf of the residents of this great watering place of America, I bid science welcome. And when your labors are ended, and you depart hence, I trust you may find your place of assembly was well chosen; and though science may raise her voice amid the pleasures of a season at Saratoga, that your deliberations may be enhanced by such association, and pleasant remembrance lead your footsteps hither on some similar occasion in the future.

PRESIDENT BARKER responded in the following words:—

On behalf of the American Association, I thank you sincerely for the kind and cordial words of welcome which you have just spoken. Indeed, it was our appreciation of these very advantages which you have so eloquently claimed for Saratoga—advantages of location, advantages of entertainment, and advantages of historic association and scientific possession—which led us at St. Louis to select this as our present place of meeting. We came here without the invitation which has in the past usually solicited us. Hence we expected but little attention and desired to hold our sessions quietly, to read and discuss our papers modestly and to depart. But we have been gratified to find that quite an unexpected interest has been awakened in our meeting. A large local committee has been appointed, composed of gentlemen whose names upon our circular is in itself a compliment. They stand responsible for us before the community and are an evidence that the American Association for the Advancement of Science does not want for friends in Saratoga. Moreover, the extent and variety of the preparations made in advance of our coming reflect great credit upon those who have had most to do with the arrangements for the meeting.

The American Association, as its name implies, is a scientific body. Using the word science in its widest sense, it maintains that, while much undetermined material may and must be collected for investigation, only that knowledge which has become actual should be garnered as wheat. In its opinion, it is the more or less crude speculation, rather than the established fact, which tends to brings science into discredit. In advancing into an unknown country, progress must undoubtedly be slow and results, for a time at least, more or less doubtful, until the ground has been most thoroughly explored and the relations of things estab-

lished. Then the antagonism of differing views and the cross-questioning of opposing opinion soon bring the truth to light and fix it as an integral part of science.

But our Association has for its object to advance knowledge not only by the discovery of new truth but also by the diffusion of that already known. To this end, it extends a cordial recognition to all organizations of whatever sort, whose objects are akin to its own. Being itself national in character—for science knows no country and no section of country—it gives its endorsement to all local enterprises which are seeking to advance science, and stands ready to assist them in any legitimate way. Whether it be a State Geological or Topographical Survey, an Academy of Science, an Association or an individual seeking to unravel nature's secrets, the American Association extends to each of them a helping hand and endorses them in the communities where they are respectively working. Its province is to awaken everywhere an interest in pure science; or, where such interest has already been awakened, to develop it to the full. It invites all interested in science to its membership and opens its sessions to all comers. That its periodical and migratory meetings, in the words of the Constitution, have actually done what they were intended to do—have promoted intercourse between those who are cultivating science in different parts of America, have given a stronger and more general impulse and a more systematic direction to scientific research and have procured for the labors of scientific men increased facilities and a wider usefulness, no one who has watched its history can doubt.

There is a recent phase of the scientific method which, from its suggestiveness, deserves an especial mention. In all ages, theoretic science has, from the nature of the case, necessarily preceded, in point of time, practical science; the discovery of the fact has preceded its application to useful purposes. The real mother of invention has been not necessity, but discovery. The telegraphic invention of Morse had been impossible except for the scientific principles established previously by the deflagrator of Hare and the electromagnet of Henry. Investigation has gathered into the great storehouse of truth the scientific fact which has subsequently been made the basis of the invention. In a very true sense science is the raw material out of which all the useful arts have been made.

But in the past, the discoverer has very generally been independent of the inventor. Rarely has the faculty for research been successfully combined with the inventive faculty in the same individual. The reasons for this are not difficult to conjecture. In the first place, the discoverer is a man of theory, the inventor a man of practice. Hence the quality of mind belonging to the two men is radically different. The former values truth the more highly for its own sake, the latter because it is capable of useful application. Again the incentive in the two cases is of an entirely different sort. It will not be denied that it is the promise of pecuniary reward which leads to the invention; nor, on the other hand,

that it is an overmastering desire to attain new truth, leading to the laborious and painstaking research, undertaken perchance at serious sacrifice of wealth and comfort, which results in the advancement of theoretic science. Moreover, the training of the practical man has been, in general, of a widely different type from that which has produced the theorist.

Within the past few years, however, observant men have noticed a change in this condition of things, and many conspicuous examples have arisen of highly successful inventors who are also investigators of a very high order. Perhaps invention has become impatient at the slow march of scientific discovery and has itself entered upon the stage in the rôle of discoverer. But however that may be, it is quite certain that no single feature of scientific method more distinctly characterizes our modern science, than the fact now adverted to. Indeed in those directions in which practical application has made the longest strides, the inventor is far in advance of the discoverer even in pure science. The great electrical discoveries, for example, which are the wonder of the century, were born of telegraphic necessities. In chemistry there are men in the foremost rank of discovery who make the practice of the chemical arts their profession. In mechanics, heat, optics, the practical man has to utilize truths which he himself has discovered and to apply laws which he has established. The time was when the theorist could solace himself with the conviction that he alone was the discoverer; when he could associate himself with a circle of other like-minded individuals to constitute an exclusive fraternity. But this time has now passed away. The man of science is he who applies truth successfully, equally with him who discovers it. This new phase of scientific method it is which the organization of the American Association is well adapted to meet. The originator and the applier of discovery are alike welcome to its membership. And if so be that the investigator becomes an inventor, or perchance the inventor turns his attention to research and enriches the world of knowledge, he contributes none the less to the advancement of science and so worthily honors his connection with us.

In what has now been said, it is obvious that reference has been had only to those departments of investigation whose results have a more or less immediate practical application of pecuniary importance. By far the larger mass of scientific knowledge, however, has no such secondary importance. Its value is intrinsic, primary. It is to be treasured because it is a part of the great ocean of truth. It is for this reason, doubtless, that the investigating faculty in man has usually been assigned a higher place in his mental composition, than the inventive faculty. The motive to investigation is a more purely unselfish one, the man being urged on in his research from his devotion to the truth alone. Men of such a stamp seem to live on a higher plane. They toil on, swerving not a hair from their self-imposed task. They have no time to make money. They patiently and laboriously carry on their investigations, resolutely denying themselves the good things of this life, the attainment of the truth being their only reward. Such men are heroes.

They are more worthy of their generation than the conqueror of a thousand battles. While then we honor original research and accord to it this high position, let us be just and impartial in our dealings. Let us recognize the equal merit of the original investigator who applies his discoveries for the benefit of mankind, with him who gathers the fruits of his labors into the great treasure-house of knowledge solely to increase the stock of truth.

In the light of this discussion, it will be seen that the facts stated by no means diminish, but very materially increase the necessity of encouraging original research. They show that in the exact proportion in which research is fostered and supported will be the resulting wealth which flows from the invention. They make it clear that poverty in the one means poverty in the other. Men appreciate at once the invention because of its money value which enriches their pockets. But it is obvious that the discovery of a new fact, which may have many and important applications, is of vastly more importance to the world, than is any single application of the fact to useful purposes. It follows therefore as a natural inference, that the only true mode of increasing the wealth of remunerative invention is the recognition and endowment of original research.

Here in Saratoga, most fortunately, we are furnished with excellent illustrative examples of the truths we are considering. Who can estimate the pecuniary advantages which have come from these mineral springs? And yet it is chemical research which has patiently gathered together the analytical data by means of which our fellow member, Professor Chandler, has been able to analyze and classify the waters of these springs and thus largely to enhance their value. Other excellent examples of the value of applied science are found in your State Surveys, both Geological and Topographical. The former of these, originated more than forty years ago and carried uninterruptedly forward to the present by our distinguished past President, Professor James Hall, has accomplished a work of incomparable value not to the State of New York alone, but to American Geology, since the order of succession which it established has been accepted as typical of the continent. Its publications indicate the work the Survey has done, and are an enduring monument to the value of scientific investigation. Twenty-three quarto volumes, extensively illustrated, have already been published upon the Botany, Zoology, Mineralogy, Agriculture, Geology and Palæontology of this state. Four volumes of the Palæontology have been completed and a fifth of over one hundred plates is nearly printed. The plates for a second part of this volume are already lithographed. Of the Corals and Bryozoa which will complete it, drawings are already made for 150 plates, and twenty-five of these are lithographed. When complete it will be the most extensive work ever issued upon Fossil Corals. The collections of this Survey, deposited in the State Museum of Natural History, furnish material for valuable annual reports containing the results of scientific investigation. The contributions to our knowledge of

the Fungi published in this way are among the most valuable in America. To a scientific work of this magnitude and excellence, the Association cannot but give its heartiest endorsement; expressing, in doing so, the hope that the splendid collection which the Survey has gathered at Albany may be preserved intact in the Museum there, for the study of generations yet to come.

The Topographical Survey of the State of New York, though only organized in 1876, already gives promise, under its efficient Director, our fellow member, Mr. James T. Gardner, of great scientific usefulness. Under the plan proposed by him for the Trigonometrical Survey, the principal belt of primary triangles is to cross the state in the latitude of the Mohawk river. It is already about half completed. The secondary and tertiary triangulation has been carried into about one-third of the counties of the state. Deeply set granite posts mark the points fixed by the Survey. Where land is most valuable, these posts are not more than a mile apart. Such monuments form a system of imperishable landmarks to which all local surveys will hereafter be referred. In addition to this work, the Survey has determined the geographical position of between three and four hundred places, among which are some of the principal cities of the state. The maps in use at present have been found totally incorrect, the cities and towns in them being misplaced from one to three miles in latitude or longitude. The triangulation has been executed with great precision and the work has progressed with rapidity and economy. It is earnestly to be hoped that topographical work may soon be begun, as not even a rude topographical map of the state of New York at present exists. Such a Survey as this must commend itself to every one as invaluable. I am sure I express the unanimous feeling of the Association when I cordially endorse the excellent arrangements already made, and express the high appreciation I have of the fidelity and accuracy with which the work already done has been accomplished.

FELLOW MEMBERS OF THE ASSOCIATION:—

I trust you will pardon me for detaining you so long from the work which you have come here to perform. The large number of members who have already arrived; the many and valuable papers whose titles have been entered; the cordiality of our reception and the pleasantness of our surroundings,—all give promise of a large and satisfactory meeting. With your kind assistance, I shall hope to discharge the duties which, as your presiding officer, you have assigned to me, with a reasonable measure of success. It now only remains for me officially to declare the twenty-ghth meeting of the American Association for the Advancement of Science formally opened.

Dr. GEORGE LITTLE of Atlanta, the General Secretary elect, not having arrived, Dr. H. CARRINGTON BOLTON of Hartford, General Secretary of the preceding meeting, was continued in the office *pro tem.*

The GENERAL SECRETARY announced the arrangements made by the Local and Standing Committees with reference to the places of meeting for the Sections and Subsections of the Association.

The recommendation of the STANDING COMMITTEE that the daily sessions should commence at 10 A. M. and continue until 3 P. M. with a recess at noon, at the discretion of the several Sections, was adopted.

The Association then proceeded to the election by ballot of six Fellows for members of the Standing Committee; Profs. A. R. Leeds and Maurice Perkins being appointed tellers, the vote was taken, and they reported the following gentlemen elected, from the eleven nominees:—

Prof. CHARLES A. YOUNG, of Princeton.
Mr. SAMUEL H. SCUDDER, of Cambridge.
Prof. HENRY MORTON, of Hoboken.
Prof. WILLIAM HARKNESS, of Washington.
Prof. FRANK W. CLARKE, of Cincinnati.
Dr. JOHN G. MORRIS, of Baltimore.

The GENERAL SECRETARY read the names of one hundred and twenty persons recommended to membership by the Standing Committee and they were unanimously elected.

The GENERAL SECRETARY read the following brief notices of deceased members:—

JOHN BOADLE, of Haddonfield, N. J., died in July, 1878, in his 74th year. He joined the Association at the 20th meeting.

Prof. MORDECAI YARNALL, of the Washington Naval Observatory, died January 27, 1879, at the age of 62. He joined the Association at the 26th meeting.

Mrs. ELIZABETH EMERSON ATWATER, of Buffalo, N. Y., died April 11, 1878, in the 66th year of her age. She joined the Association at the 17th meeting.

Mrs. F. W. PUTNAM, of Cambridge, Mass., died March 10, 1879, in her 40th year. She joined the Association at the 19th meeting.

Rev. CHARLES H. BRIGHAM of Ann Arbor, Mich., died in February, 1879, aged 59 years. He joined the Association at the 17th meeting.

Mr. FREDERICK A. CAIRNS, Instructor in Analytical Chemistry, School of Mines, Columbia College, New York, died in the Spring of 1879. He joined the Association at the 27th meeting.

PRESIDENT BARKER announced that the Standing Committee at the preceding meeting of the Association recommended an amendment to Article 35 of the Constitution, and a year having elapsed the time had arrived for taking a vote on the proposed amendment. The object of the alteration is to entitle Life Members to receive the annual volumes of the Proceedings without further assessments. The Article with the proposed amendment is as follows:

"Any member or fellow who shall pay the sum of fifty dollars to the Association at any one time shall become a Life Member, and as such

shall be exempt from all further assessments and shall be entitled to the Proceedings of the Association. All money thus received shall be invested as a permanent fund, the income of which shall be used only to assist in original research unless otherwise directed by unanimous vote of the Standing Committee."

After brief discussion, a rising vote was taken and more than three-fourths of the members voted affirmatively; the President accordingly announced the adoption of the amendment.

Dr. H. CARRINGTON BOLTON expressed his satisfaction at the change in the Constitution and requested the Permanent Secretary to add his name to the list of Life Members of the Association.

Thereupon the following gentlemen requested their names be added to the list of Life Members: —

General WILLIAM LILLY.
Mr. P. W. SHEAFER.
Dr. P. O. WILLIAMS.
Mr. S. H. SCUDDER.
Prof. C. V. RILEY.
Mr. THOMAS BASSNETT.

The Association then adjourned to meet in Sections.

Section A met in the "Trustees' Room," Town Hall, and was called to order by the Vice President Prof. S. P. LANGLEY of Allegheny; the Secretary Prof. JOHN K. REES being in attendance. The following gentlemen were elected members of the Sectional Committee: —

Prof. A. W. WRIGHT, of New Haven.
Prof. JOHN TROWBRIDGE, of Cambridge.
Prof. W. A. ROGERS, of Cambridge.

Section B met in the large hall of the Town Hall and was called to order by Vice President Major J. W. POWELL.

In the absence of the Secretary elect, Prof. A. G. WETHERBY, of Cincinnati, Capt. W. H. DALL, of Washington, was elected Secretary of the Section.

The following gentlemen were elected members of the Sectional Committee: —

Prof. C. H. HITCHCOCK, of Hanover.
Prof. J. M. SAFFORD, of Nashville.
Mr. WILLIAM SAUNDERS, of London.

The Permanent Subsection C met in the smaller room, Town Hall, and was called to order by Prof. F. W. CLARKE, of Cincinnati, who stated that the Chairman elect, Prof. IRA REMSEN, of Baltimore, was unable to be present.

On motion, it was voted that Prof. F. W. CLARKE, the Chairman of the preceding meeting, be continued in office.

Prof. WILLIAM RIPLEY NICHOLS, of Boston, was elected Secretary and the Section adjourned.

Members of the *Permanent Subsection D*, by reason of the small attendance, met with Section A.

Thursday, August 28th. The Second Day's Session was opened in the Town Hall at 10.30 A. M., President BARKER in the Chair.

The recommendation of the STANDING COMMITTEE that Sections A and B exchange rooms for the day was adopted.

Owing to the non-arrival of DR. GEORGE LITTLE, the General Secretary elect, the Standing Committee recommended to the Association that the vacancy be filled by Dr. H. CARRINGTON BOLTON. The recommendation was adopted and Dr. Bolton was elected General Secretary.

The GENERAL SECRETARY announced that the Permanent Subsection C would postpone meeting until after the noon recess, in order to give members an opportunity of hearing the Address of the Chairman Dr. IRA REMSEN, which would be read before Sections A and C in joint session.

The GENERAL SECRETARY read the following telegram, which was received by the Association with lively expressions of satisfaction.

NEW YORK, AUGUST 27, 1879.

F. W. PUTNAM,

Secretary A. A. A. S.

I regret that I cannot attend your meeting this year, imperative duties preventing. Dr. Green, our President, hereby extends to the members of the Association the free use of the Western Union wires for the transmission of family, social, and scientific messages during your session. I trust that the meeting may be fraught with progressive information and personal enjoyment.

The recommendation of the STANDING COMMITTEE, that the Permanent Secretary be requested to return thanks to Mr. Somerville for his courtesy, was unanimously adopted.

The GENERAL SECRETARY presented the following letter from Mr. J. P. HASKINS.

To the EXECUTIVE COMMITTEE of the A. A. A. S.

The undersigned would respectfully ask you to announce, that he has an extensive collection of minerals, fossils and antiquities collected in the vicinity of Saratoga Springs, which is open for examination to those interested in these subjects, and he cordially invites those who might desire information upon the local geology on the localities of this vicinity to call and examine the same.

The collection will be found at Nos. 551 and 553 North Broadway.

Respectfully, J. P. HASKINS.

Mr. S. H. SCUDDER read a "Notice of a Catalogue of Scientific Serials."

President BARKER made complimentary remarks on the same.

The names of thirty-five persons recommended to membership by the STANDING COMMITTEE were read, and the persons were elected.

President BARKER announced that the Address of the Retiring Presi-

dent, Prof. O. C. MARSH, would be delivered on the evening of Thursday, and the Addresses of Vice Presidents S. P. LANGLEY and J. W. POWELL, on Friday evening.

The General Session then adjourned to meet in Sections.

At 8 P. M., the Address of the Retiring President, Prof. O. C. MARSH of New Haven, was delivered before the Association in General Session at the Town Hall.

Friday, August 29th. The Third Day's Session was opened at 10.30 A. M., President BARKER in the Chair.

President BARKER requested the members of Sections A and B to choose their respective Nominating Committees at their meetings to-day.

Eighteen persons, recommended to membership by the Standing Committee, were unanimously elected.

The GENERAL SECRETARY made the following announcements:—

Newly elected and newly arrived members are requested to register their names and receive their certificates at the Office of the PERMANENT SECRETARY, room 14 in the Town Hall.

The Entomological Club of the Association will meet at 4 P. M., in the room of Section A.

The PERMANENT SECRETARY called attention to the rules requiring that every paper, or an abstract of it, must be sent to the Standing Committee through the Permanent Secretary, before the title can be transmitted to the Sectional Committee. He also called for abstracts of certain papers.

Mr. W. H. H. RUSSELL of St. Louis presented the following resolutions:—

"*Whereas*, The people of California are noted the world over for their genial hospitality and marked spirit of enterprise. *Therefore be it Resolved*, That when this Association adjourns, it adjourns to meet in the City of San Francisco on the 15th day of August, A. D., 1880.

"*Resolved*, That the special enquiry in yesterday's *Saratogian* upon the subject matter as to the best mode of preserving the Florida Orange be referred to the distinguished Vice President of Section B, with the request that he report at this meeting upon the important enquiry as to the best mode for preserving North American Oranges."

Both resolutions were referred to the Standing Committee.

President BARKER announced the several assembly rooms assigned for the day to the Sections and Subsections.

Prof. SIMON NEWCOMB introduced to the Association Prof. OTTO STRUVE, Director of the Imperial Observatory at Pulkowa, Russia, who was received with cordial applause.

Prof. OTTO STRUVE addressed the audience and expressed his thanks for the courteous welcome extended to him. He stated that the Emperor of Russia desired to provide the Pulkowa Observatory with the finest telescope that could be made, and after visiting all the establishments in Europe, Prof. Struve concluded he must come to the United States to get the

best instrument. The high reputation of the instrument-makers of Cambridge, Alvan Clark & Son, who made the great refractor at Washington, was well known to him, and he was happy to state that they had agreed to supply his want, and would make the lens for the largest refracting telescope in the world. Prof. Struve expressed his pleasure at the opportunity of attending the meeting of the Association and his appreciation of the honor paid him.

President BARKER then welcomed Prof. Struve in a felicitous speech.

The meeting adjourned to meet in Sections.

In Section A the following gentlemen were elected members of the Nominating Committee:—

Mr. W. H. PULSIFER, of St. Louis.
Prof. J. R. EASTMAN, of Washington.
Prof. JOHN TROWBRIDGE, of Cambridge.
Mr. P. W. SHEAFER, of Pottsville.

In Section B the following gentlemen were chosen members of the Nominating Committee:—

Prof. S. S. HALDEMAN, of Chickies.
Prof. C. H. HITCHCOCK, of Hanover.
Rev. Dr. E. A. DALRYMPLE, of Baltimore.
Prof. W. C. KERR, of Raleigh.

Subsection E, Anthropology, organized by electing Dr. DANIEL WILSON of Toronto, *Chairman* and Mr. J. G. HENDERSON, of Winchester, *Secretary*.

At 8 P. M., the Addresses of Vice Presidents S. P. LANGLEY and J. W. POWELL were delivered in General Session at the Town Hall.

Saturday, August 30th. The Fourth Day's Session was called to order at 10.30 A. M., President BARKER in the Chair.

President BARKER announced that vacancies having occurred in the SPECIAL COMMITTEES, the Standing Committee recommended that these vacancies be filled by the appointment of the following gentlemen, viz.:—

Prof. JNO. TROWBRIDGE of Cambridge, and Prof. ALFRED M. MAYER of Hoboken, to fill two vacancies in the Permanent Committee on Weights, Measures and Coinage."

Mr. JAMES T. GARDNER of Albany to fill the vacancy in the "Committee to memorialize the Legislature of New York for a New Survey of Niagara Falls."

The recommendation was adopted and the vacancies filled as stated.

The GENERAL SECRETARY read the following notice:—

In this room, soon after 3 o'clock this afternoon, Prof. Wilder will perform some experiments upon an etherized cat by electrical irritation of the brain and nerves. Persons interested are invited to attend.

Eighteen persons recommended for membership by the Standing Committee were elected.

The General Session then adjourned to meet in Sections.

At 8 P. M., a General Session was held in the Town Hall. President BARKER, being in the Chair, introduced Dr. THOMAS A. EDISON of Menlo Park, and after a rapid sketch of the discovery and the development of the telephone in its various forms, announced Dr. Edison's paper on the Electro-chemical Telephone.

Dr. Edison illustrated his remarks by sketches on the blackboard.

Experimental illustrations of the Electro-chemical Telephone were then given by Dr. Edison assisted by Dr. Barker.

Adjourned.

Monday, September 1st. The Association met in the "Armory" on the third floor of the Town Hall at 10.15 A. M. President BARKER in the Chair.

Reports of Special Committees being called for, the GENERAL SECRETARY stated that the Committees (No. 1) on Weights, Measures and Coinage, (No. 2) to memorialize the Legislature of New York for a New Survey of Niagara Falls, and (No. 3) to memorialize Congress and State Legislatures regarding the Cultivation of Timber and the Preservation of Forests, had not presented reports. On motion, the Association voted to continue each of these committees.

The Report of the Committee (No. 4) on International Congress of Geologists being called for, Prof. JAMES HALL, chairman, presented the following statement.

At the Nashville meeting, in 1877, the committee reported that since its organization in Buffalo in 1876, its labors had resulted in arranging with the Geological Society of France for an International Congress of Geologists in Paris, in August, 1878. The Congress met on August 29, and six sittings were held. The whole number of members enrolled was 328, of whom about 250 were in attendance. American geology was represented at the congress by J. P. Lesley, T. Sterry Hunt, James Hall, George H. Cooke, W. P. Blake, E. D. Cope and T. C. Chamberlin. Canada, Spain, Portugal, Italy, Switzerland, Belgium, Holland, Denmark, Norway, Sweden, Russia, Austro-Hungary and Roumania were represented, but neither England nor Germany. Forty papers were communicated, covering a wide range of subjects, and often giving rise to important discussion. The proceedings are soon to be published, at the expense of the French Government.

It was decided that the second session of the International Congress should be held at Bologna, Italy, in 1881, under the honorary presidency of President Sella, of the Academia dei Lincei, of Rome. A local committee of Italian geologists was named, and have issued a circular. The Congress will be opened September 29, 1881. The principal subjects proposed for consideration are comprised under two groups, and for each of these an international committee was named by the Congress of Paris. The first of these is to consider the question of geological maps, and the arrangement of a common system of signs and colors—the "*unification des figures géologiques.*" The second is for the unification of geological nomenclature, under which head, as interpreted by the Congress, will be considered all questions relating to geological classification, as well as

to the value and significance of mineralogical, lithological and palæontological characters, thus embracing many of the most important problems of geology. In naming these, so far as possible, one member was appointed for each country, whose duty it shall be to organize therein local committees, and to communicate both with the Secretary of the Council of the Paris Congress (of which the powers are continued until the meeting in 1881), and with the local committees at Bologna.

For the Committee on Maps the American members are Professor Lesley for the United States and Professor Selwyn for Canada, and for that on Geographical Nomenclature, Professor James Hall for the United States and Professor T. Sterry Hunt for Canada. Active preparations are already made in Great Britain and Germany for representation at the Bologna Congress.

In view of the fact that the work of an International Geological Congress was initiated by this association, and that it promises to become of permanent and increasing importance, it is believed that it will be for the best interests of geological science that this committee be continued, with power to add to its number; and, further, that its scope may with advantage be extended to include the consideration of such questions relating to State or National geological surveys as may from time to time arise.

On motion of Major POWELL the Report was accepted and the recommendation of the committee was adopted.

Dr. T. STERRY HUNT

Moved, That inasmuch as the European members of this committee will henceforth be engaged as members of local committees for the coming session of the Congress in their respective countries, their names be dropped from the present committee.

Adopted.

Voted, That committee (No. 5) to Memorialize Congress in relation to the Yellowstone National Park be continued.

Voted, That committee (No. 6) on the Introduction of Science into the Schools be discharged, and that a Committee on Science Teaching in Public Schools be constituted, consisting of:—

Dr. E. L. YOUMANS, of New York.
Prof. AUG. R. GROTE, of Buffalo.
Major J. W. POWELL, of Washington.
PROF. N. S. SHALER, of Cambridge.
Dr. J. S. NEWBERRY, of New York.

Dr. E. L. YOUMANS then read the following paper by JAMES SAMUELSON, President of the Liverpool Science and Art Classes, on the Operations of the Science and Art Department of the Privy Council of Great Britain:—

As it appears to me, during the short tour which I am making through the United States, to be a wide field for the diffusion of scientific knowledge, both practical and theoretical, among the industrious classes of this country, I venture to lay before your Association a brief notice of

the operations of our science and art department, so far as science teaching is concerned. And my right to do so is based on the fact that I have not only founded three or four science schools, but that I have actively promoted the leading objects of the department almost from its foundation, and am therefore intimately acquainted with the objects and working of the system.

The Science and Art Department of our Committee of the Privy Council on Education was founded by an "order in Council," February 26, 1856, under the provisions of an act of Parliament. The object of the department is to promote science instruction chiefly among the industrial classes, and the means employed are:

I. Payments to teachers on results shown by the annual May examinations. These examinations are conducted simultaneously all over the three kingdoms by printed papers prepared by the examiners, who are selected from our leading scientific men.

II. Queen's prizes, being scientific books selected by the successful students from a catalogue sent down by the Department; also gold and silver medals (competitive), one of which is given for each branch of science.

III. Exhibitions, scholarships, studentships, etc. Among these are "studentships for training," which give the student the privilege of attending the science classes at South Kensington at the charge of the State; also the well-known Whitworth scholarships of £100 per annum for three years for practical and theoretical proficiency.

IV. Grants toward a building fund for the erection of science schools.

V. Grants toward apparatus and school fittings.

VI. Laboratory grants.

VII. Payments in aid of training teachers.

The subjects in which instruction is given are twenty-four in number, and the number of schools in which instruction is imparted, chiefly in the evenings, is at present nearly 1,500. In order to give you an idea of the growth of the system I will give you a few figures.

For some time after the foundation of the department only five towns responded, and of the five schools so founded one or two were unsuccessful, and were closed. In 1861, I had the honor of founding the Liverpool School of Science, the first established there, and the system was already so far developed that we enrolled between 100 and 200 students. In 1867 there were 213 schools in Great Britain giving instruction to about 10,000 of both sexes; in the session of 1876–1877, 1,348 schools with over 55,000 students. Owing to stricter regulations being enforced, the number of students diminished in 1877–1878, being 52,330, but the schools multiplied, there being 1,484, with 4,559 classes. The fruits of the system are widespread. Every large town has many schools, London alone having 165, and the smaller towns and even villages have their classes, the students of which are often more successful than those of the more important centres of learning and industry.

Now let me endeavor to explain briefly how the various localities secure the benefits offered by the department:

A committee of gentlemen, not less than five in number, and one of whom must be a clergyman or magistrate, is formed in any locality for the purpose of managing the classes. This committee places itself, through its secretary, in communication with the department, engages the teachers, who must be "certificated;" and so the "science school" is formed. All payments are made to the committee, who may, if they please, retain one-fifth of the teachers' fees for cost of management. In order to understand the mode of proceeding we must pass on to the May examinations. The papers at these examinations are framed to include six grades of students who may pass as follows: Elementary, first and second class; advanced, first and second class; honors, first and second class. As soon as a student has passed in the second class of the advanced stage, he is entitled to earn payments on results; in fact, he is a "certificated" teacher of the department. He must give twenty-five lessons (class lectures) in any subject which he teaches before he can receive payment for his instruction. This payment is in proportion to the degree of success attained by his pupils, and in no case exceeds £4 ($20) for each student. As a matter of fact, any industrious and intelligent student may enable his teacher to earn this amount.

It is impossible in a short paper to enter into the details of the system, but I will mention a few of the subjects taught as they occur to my memory: Biology in all its branches (including botany and vegetable physiology); physics (acoustics, light and heat, magnetism and electricity); physical geography, now known as "physiography;" every branch of mathematics; chemistry (organic and inorganic); building construction, steam naval architecture, geology, mineralogy, mining, etc., etc.

A word or two as to the advantages of the system. It is making our men better mechanics. It is training 50,000 people to-day to think systematically, and to reason without passion or prejudice; to appreciate your "Cooks" and your "Ingersolls," and by their influence to enable those about them to form correct estimates of the value of public utterances on scientific and philosophical questions. It is enabling many young persons who would have drudged at the desk or counter all their lives to earn an additional income by science teaching, and others to form a higher estimate than their ordinary avocations present of life and of the world in which they live. It is influencing our homes, by giving to people about to enter life more rational views of sanitary matters, and all others pertaining to health and disease; and, last but not least, it is expanding the views of young people, educated it may be in some rigid, restricted, though devotional, school of thought, and making them more charitable in their opinions of those who differ from them on religious questions. In fact, it is materially beneficient to the teacher, morally advantageous to the taught, and beneficient in its general influence on society.

This communication was referred to the Committee on Science Teaching in the Public Schools.

Voted, To continue the following Committees:—(No. 7) "On the Relation of Science to the Industrial Arts;" (No. 8) "Committee to Memorialize Congress in relation to Meteorological Researches," and (New No. 1) "Committee to obtain Permanent Funds for the Association, and to advise with Treasurer and Permanent Secretary on financial matters."

Voted, To discharge the Committee on Membership, and that a new Committee on Membership be appointed to consist of the Standing Committee of the Association.

Dr. H. CARRINGTON BOLTON then read the rough draft of a Circular which he proposed should be issued by the Committee on Membership to solicit the coöperation of scientific men, not already members of the Association, and yet who sympathize with its aims and operations.

The Circular was referred to the Standing Committee.

The Committee (New No. 3) to prepare a Eulogy on the late Joseph Henry, having reported progress, was discharged.

The names of nineteen persons recommended by the STANDING COMMITTEE to membership were read by the GENERAL SECRETARY and they were elected by ballot.

The GENERAL SECRETARY then read the names of thirty-six members nominated for fellowship by the Standing Committee, as follows:—

Prof. PETER TOWNSEND AUSTEN, Rutgers College, New Brunswick, N. J.
AD. F. BANDELIER, Highland, Ill.
Prof. ALEXANDER GRAHAM BELL, Boston University, Boston, Mass.
GARLAND CARR BROADHEAD, Pleasant Hill, Mo.
Major T. B. BROOKS, Geologist State Surveys of Michigan and Wisconsin, Newburgh, N. Y.
ECKLEY B. COXE, Drifton, Luzerne Co., Pa.
Prof. HENRY DRAPER, New York City.
Capt. JAMES B. EADS, St. Louis, Mo.
Prof. J. R. EASTMAN, U. S. Naval Observatory, Washington, D. C.
Prof. THOMAS EGLESTON, School of Mines, Columbia College, New York City.
S. F. EMMONS, Cheyenne, Wyoming Territory.
Prof. S. A. FORBES, Normal, Ill.
Prof. PERSIFOR FRAZER, Jr., Assistant Geologist 2nd Geological Survey of Pennsylvania, Philadelphia, Pa.
JAMES T. GARDNER, American Geographical Society, New York.
EDWARD GOODFELLOW, Assistant U. S. Coast Survey, Washington, D. C.
ARNOLD HAGUE, 23 Fifth avenue, New York City.
OSCAR HARGER, Yale College Museum, New Haven, Conn.
JOHN G. HENDERSON, Winchester, Ill.
Rev. A. B. HERVEY, Troy, N. Y.
Prof. ROLAND D. IRVING, Wisconsin Geological Survey, Madison, Wis.
THOMAS POTTS JAMES, Cambridge, Mass.
Prof. CHARLES A. JOY, Stockbridge, Mass.
Prof. ABRAM LITTON, Washington University, St. Louis, Mo.
Lieut. Col. GARRICK MALLERY, U. S. A., Washington, D. C.

EDWARD L. MARK, Fredonia, N. Y.
Prof. DANIEL S. MARTIN, 236 West Fourth street, New York.
A. A. MICHELSON, Ensign U. S. Navy, Annapolis, Md.
Prof. A. W. PHILLIPS, New Haven, Conn.
Prof. W. B. POTTER, Washington University, St. Louis, Mo.
Mr. W. H. PULSIFER, St. Louis, Mo.
Dr. CARL ROMINGER, Ann Arbor, Mich.
P. W. SHEAFER, Pottsville, Pa.
Prof. JOHN C. SMOCK, Rutgers College, New Brunswick, N. J.
Dr. GEORGE VASEY, Department of Agriculture, Washington, D. C.
LESTER F. WARD, Treasury Department, Washington, D. C.
Capt. GEORGE M. WHEELER, U. S. E., Washington, D. C.

The PRESIDENT appointed Profs. NASON, KERR, HITCHCOCK and EASTMAN to act as tellers; ballots were cast, and teller Hitchcock reported all the proposed fellows had received the necessary number of votes.

The PRESIDENT then declared the members named elected to fellowship.

Prof. D. S. MARTIN introduced the following Resolution:—

Resolved, That in view of the great economic importance of the matter of forest-protection and wood-culture, in charge of Committee No. 3, the Association would express its earnest desire that some report looking toward definite action be received from the Committee at the next meeting of the A. A. A. S.

The Resolution was referred to the STANDING COMMITTEE.

Prof. A. H. WORTHEN introduced the following Preamble and Resolution:—

Whereas, The subject-matter of the paper to be read this morning in Subsection E by Prof. Bickmore, "On the Origin and Distribution of the Human Race on this Planet," is of such general interest to the members of this Association, that all should have an opportunity of listening to the important facts presented, therefore be it

Resolved, That Prof. Bickmore be requested to prepare another paper upon this interesting subject to be read in General Session at the next meeting of this Association.

The Resolution was referred to the STANDING COMMITTEE.

The GENERAL SECRETARY then stated that the STANDING COMMITTEE, in joint session with the NOMINATING COMMITTEE, had unanimously voted to recommend to the Association to hold the next meeting in Boston, on the last Wednesday in August.

It having been moved and seconded to accept this recommendation of the Nominating Committee, Prof. WM. B. ROGERS of Boston addressed the Association as follows:—

As I am in a sense personally responsible for initiating this recommendation, I wish to say a few words. Before coming to Saratoga I had formed no definite opinion as to the place where we were to assemble

next year. But remembering that Boston has never yet had the benefit of the presence of this Association, and thinking of the various attractions and advantages which it offers as a place for our meeting, I have felt it a duty to urge the invitation which has just received from this company such a cordial response.

A younger man might better have assumed the responsibility of this proposal as he could better promote its success by his personal efforts, and were I otherwise surrounded than I am, although I should exert myself to the same extent, I might feel some hesitation. But as it is, I know well the band of young workers that encompasses me. I know the wide resources and the large and generous hospitality which characterize the city of Boston. I know that we can furnish there the most admirable facilities for carrying out the business of the Association, and I have been inspired to make this movement from my appreciation of the value of these facilities. At the Institute of Technology and at the neighboring building occupied by the Boston Society of Natural History, there is abundant room. We have a large hall for the general sessions of the Association and smaller halls for the sectional meetings. There is a large expanse of blackboard and convenient apparatus, with motive power to carry on experiments and exhibitions. Although I am not prone to make exclusive boast of Boston and its fine vicinities, feeling as I do strong affiliation, through long experience as a teacher, with the Middle and Southern sections of the Union, yet I am perfectly sure that in no place can this Association be more fitly represented and its wants be more fully met than in the City of Boston. I can guarantee these various advantages, and that those acting with me will be so seconded by the city and citizens as to secure the financial aids and the hospitality which the Association has been accustomed to look for and which it so signally deserves. The men of science, the workers for its ends, need and deserve support and appreciation, and the best that our civilization can offer. I unhesitatingly guarantee the Association a large meeting at Boston, and a large, grateful, and appreciative public to welcome them there.

Messrs. S. H. SCUDDER, H. L. EUSTIS and F. W. PUTNAM also addressed the meeting and made brief statements concerning the facilities which would be placed at the service of the Association at Boston, and assured the members of a cordial welcome and reception on the part of the people of Boston and Cambridge.

The recommendation of the NOMINATING COMMITTEE was then unanimously adopted.

The GENERAL SECRETARY read the names of the gentlemen recommended by the NOMINATING COMMITTEE for general Officers of the Association for the ensuing year; viz. :—

President,—LEWIS H. MORGAN, of Rochester.
Vice President, Section A,—ASAPH HALL, of Washington.
Vice President, Section B,—ALEXANDER AGASSIZ, of Cambridge.
Permanent Secretary,—F. W. PUTNAM, of Cambridge.

General Secretary,—JOHN K. REES, of St. Louis.
Secretary of Section A,—HENRY B. NASON, of Troy.
Secretary of Section B,—C. V. RILEY, of St. Louis.
Treasurer,—WILLIAM S. VAUX, of Philadelphia.
Auditing Committee,—HENRY WHEATLAND, of Salem.
THOMAS MEEHAN, of Philadelphia.

President BARKER called attention to the fact that the Permanent Secretary was to be elected for the period of five years.

On motion, the recommendation of the Nominating Committee was accepted and all the nominees were elected.

The GENERAL SECRETARY read the following letter from the Chairman of the Reception Committee, Gen. W. B. FRENCH.

AUG. 30, 1879.

TO THE STANDING COMMITTEE OF THE A. A. A. S.

The Local Reception Committee of the A. A. A. S. beg leave to inform the Standing Committee that arrangements have been made for an informal reception of the members of the Association and their friends in the Ball Room of the United States Hotel, on Monday evening next at 9.30 and earnestly request that they accept the same.

W. B. FRENCH,
Chairman Reception Committee.

The STANDING COMMITTEE having recommended acceptance of this invitation, the Association voted to adopt the recommendation.

Captain A. R. MCNAIR, Chairman of the Excursion Committee, announced that he would furnish members with certificates entitling them to obtain R. R. excursion tickets at favorable rates, and that he would be found daily from 5 to 7 P. M. in Parlor B of the United States Hotel.

Captain MCNAIR also gave notice that Messrs. Witherbees, Sherman & Co., proprietors of the Mt. Moriah Iron Mine, near Port Henry, extended an invitation to all the members of the Association to visit the interesting mines, and tendered an excursion train from Port Henry to the mines and return. Captain McNair requested members intending to take advantage of this offer to register their names in a list provided in room No. 14 in the Town Hall.

The GENERAL SECRETARY gave notice that the STANDING COMMITTEE recommended to the Sections that papers be limited to thirty minutes. He also stated that the STANDING COMMITTEE requested the Subsections to choose their Secretaries for the ensuing meeting; the custom being to elect chairmen only.

President BARKER announced a General Session in the Methodist church on Washington St., at 8 P. M.

The Association then adjourned to meet in sections.

At 8 o'clock in the evening of the same day the Association met in General Session in the Methodist church, President BARKER in the chair. Prof. C. F. CHANDLER presented a paper upon the Chemistry of the Min-

eral Waters of Saratoga, Prof. JAMES HALL spoke on the Geology of Saratoga Springs and vicinity, and Dr. T. STERRY HUNT upon the Genesis of the Springs.

The SECRETARY of SUBSECTION C reported the following gentlemen elected Officers of the Subsection for 1880.

Chairman,—JOHN M. ORDWAY, of Boston.
Secretary,—C. E. MUNROE, of Annapolis.

The SECRETARY of SECTION B reported the formation of a Subsection of Biology,—SUBSECTION F, with the following Officers:

Chairman,—BURT G. WILDER, of Ithaca.
Secretary,—LOUIS ELSBERG, of New York.

The SECRETARY of SUBSECTION E reported the following gentlemen elected Officers of the Subsection for 1880:—

Chairman,—J. W. POWELL, of Washington.
Secretary,—J. G. HENDERSON, of Winchester.

Tuesday, September 2d. The Sixth Day's Session was called to order by President BARNARD, at 10 A. M.

The names of the persons recommended to membership by the STANDING COMMITTEE were read by the GENERAL SECRETARY, and a vote being taken they were elected.

Prof. F. W. CLARKE offered the following Resolution:—

Resolved, That the thanks of the Association be given to Dr. R. C. McPherson, Gen. W. S. Pierce, Prof. E. A. Wilson, Lieut. Commander A. R. McNair, and the other officers of the Local Committee for their kindness and hospitality in arrangements for the present meeting and

Resolved, That as a token of appreciation of the work of the Association during the past year, the Members of many Scientific Societies in the United States, who have enjoyed the privileges of the Associated

The Resolution was unanimously adopted.

The STANDING SECRETARIES have received the following communications from Societies proposing to hold their next Meetings in connection with the Association:

The Secretary of the Society of Natural History of Boston, Mass., writes that the Society will hold its Annual Meeting in Boston, beginning on the last Wednesday in August, 1880.

GENERAL REPORT OF THE PERMANENT SECRETARY.

THE preceding report of the General Secretary for the Saratoga Meeting contains nearly all that it is necessary to state in relation to the Twenty-eighth Meeting of the Association, with the exception of the few statistics which it has been customary to give in each volume.

Two hundred and fifty-six members signed the register during the meeting and these were accompanied by about thirty ladies who were not members. Two hundred and nineteen persons were elected members. Of this number 152 have accepted membership and have paid their entrance fees and assessments. Thirty-six members were made fellows.

The total number of members who have paid their assessments for the Saratoga meeting to this date, including life members, is 720.

One hundred and fifty-two papers were entered on the general list of titles. Of these, eight were declined by the Standing Committee as not coming within the scope of the Association or for other reasons; four were withdrawn by their authors and four were not considered by the Committee for want of abstracts, four were read in General Session and the 132 remaining were either read in full, or by abstract or title, before the several sections as follows: Section A, 40; Section B, 54; Subsection C (Chemistry), 22; Subsection E (Anthropology), 16.

The total number of members on the lists of the Association at this date is 1030, but of this number 153 are in arrears for the St. Louis and Saratoga assessments and 162 for the Saratoga assessment only.

Notices of the decease of six members were read at the Saratoga meeting.

One thousand copies of the St. Louis volume were received from the printer in June, 1879, of which 914 have been distributed to this date as follows: — to members 735, by vote of the Standing Committee, including exchanges, 165, sold 14, leaving only 89 on hand for members who will become entitled to them by the payment of their assessment, and for future use. All the copies of the 26th (Nashville) volume have been disposed of, and a new edition should be printed as soon as the financial condition of the Association will permit. The same is the case with volume two. A few years ago volume one was reprinted. Owing to the recent increase in the number of members the Standing Committee ordered that the number of copies of the present volume should be increased to 1250. It is probable that a still larger edition will be required in future.

Owing to various causes, beyond the control of the Permanent Secretary, the present volume has been greatly delayed in passing through the press. That this, however, may not be regarded as a bad precedent, it may be stated here that arrangements are already perfected for the early publication of the Boston volume, and if authors will leave their papers

with the Secretaries immediately after reading them, so that no time will be lost in their consideration by the Publication Committee, there is every reason to believe that the next volume will be pushed through the press with great rapidity.

Owing to the financial condition of the Association, the Standing Committee were compelled to request authors in the present volume to furnish the illustrations for their papers at their own expense, and the Association is therefore indebted to several of the members for their liberality in this respect.

The cash account given on the following pages covers the period embraced between August 13, 1878 and August 23, 1879. The deficit of $187.91 shown by the account has been met in part by the generosity of the Treasurer, who has given $100.00 for the purpose, since the account was presented at Saratoga.

F. W. PUTNAM,
Permanent Secretary.

SALEM, July 30, 1880.

F. W. PUTNAM, PERMANENT SECRETARY,

Dr. THE AMERICAN ASSOCIATION FOR

1878-79.

To Balance from last Account		$ 106 76
Assessments previous to 27th Meeting . .	$ 342 00	
" for St. Louis, " " . .	1,371 00	
" " Saratoga, 28th " . .	537 00	
Entrance Fee, Buffalo	5 00	
" " Nashville	5 00	
" " St. Louis	540 00	
" " Saratoga	10 00	
Fellowship Fees	28 00	
		2,838 00
Publications sold, and Binding		130 41
Donation from W. B. Rogers		100 00
Postage charges refunded		8 39
Express " "		20
Am't paid for setting glass refunded		3 00
Life Membership commutation		100 00
Balance due Permanent Secretary		187 91
		$3, 474 67

SALEM, MASS, August 23, 1879.

I have examined the above account and certify that

IN ACCOUNT WITH

THE ADVANCEMENT OF SCIENCE.		Cr. 1878-79.
By Expenses of St. Louis Meeting:—		
General Expenses at St. Louis		$ 227 97
Expenses St. Louis vol., 1,000 *copies:—*		
Composition, Paper and Press-work	$ 1,143 98	
Illustrations	25 25	
Binding 965 in Paper, 10 in ½ Turkey, 25 in Cloth, and 25 cloth covers	234 50	
Wrapping 865 for distribution	11 50	
Distribution by Mail, $94 95; by Express, 2 20	97 15	
Extra Copies, Addresses and Reports . . .	52 37	
		1,564 75
General and Office Expenses:—		
Printing Circulars, Blanks, Tickets, etc. . .	92 31	
Binding Back Volumes	7 48	
Receipt Book	6 50	
Stamped Envelopes and Postage	166 05	
Express	59 80	
Telegrams	91	
Rent of Office to July 1, 1879 (one year) .	100 00	
Fuel	26 25	
Janitor	25 00	
Book Shelves and Cases	32 88	
P. O. Box Rent	4 00	
Subscription to "Postal Guide"	1 50	
Minor Office Expenses and Stationery . . .	35 16	
Back volumes bought	2 63	
Saratoga Meeting	21 48	
		581 95
Life Membership Fund		100 00
Permanent Secretary, Salary for 1878–79 . . .		1,000 00
		$3,474 67

the same is correctly cast and properly vouched.

HENRY WHEATLAND, *Auditor.*

INDEX.

	Page
Achromatic Telescopes, Color Correction	96
Act of Incorporation	xviii
Address of S. P. Langley	51
—— —— John W. Powell, Vice President, Section B	251
—— —— Ira Remsen, Chairman, Subsection of Chemistry	213
—— —— Retiring President	1
Air, Analyses	229
Alvord, Benj., Title of paper	209
American Association of Geologists and Naturalists, Meetings	xv
American Timbers	192
Archæology of Champlain Valley	528
Atomic Weights	230
Austin, E. P., Title of paper	210
Barker, George F., A Curious Case of Crystallization of Canada Balsam	169
—— —— —— —— Conversion of Mechanical Energy into Heat by Dynamo-electric Machines	160
Barnard, F. A. P., Title of paper	210
—— W. S., Some interesting Insect-habits and their development	472
—— —— The Bud-blight Insect	478
Beebe, William, Title of paper	209
Beet-root Culture	242
Bell, A. G., Titles of papers	210
Bolton, H. C., Report	541
—— —— The Occurrence of Microscopic Crystals in the Vertebra of the Toad (Bufo Americanus). With a note by Alexis A. Julien	415
Bornean Orangs	438
Boss, Lewis, Determination of Solar Parallax at the Opposition of Minor Planets	123
—— —— Modern Star Places with Suggestions relative to Future Coöperation among Meridian Observers	106
Boston Meeting, Local Committee	xiii
—— —— Officers	xii
Breneman, A. A., Titles of papers	248
Brocklesby, John, Title of paper	209
Butterflies, Pupation	455
Canada Balsam, Crystallization	169
Cash Account of Permanent Secretary	566
Cat, Inter-articular Ligament of the Head of the Ribs	421
Champlain Valley, Notes on the Archæology	528
Chandler, C. F., Title of paper	248
Chemical Notes	236
Clarke, F. W., Preliminary Notice of a Revision of the Atomic Weights	230
—— —— Title of paper	248
Committee, International Geological Congress, Report	43
—— Local, Boston Meeting	xiii
—— —— of Saratoga Meeting	viii
Committees of Sections, Saratoga Meeting	vii
——Special	x
Communications, Titles of	209, 248, 487, 540

	Page
Comstock, J. Henry, On a New Predaceous Lepidopterous Insect	467
Constitution	xix
Cotton Worm	464
Crystals in the Vertebra of the Toad	415
Currier, John M., Description of a Polished Stone Implement found in Monkton, Vermont	526
Deceased Members	lv
Doctrine of Chances	190
Double Stars, Observations of	65
Draper, Henry, Discovery of the Coincidence of the Bright Lines of the Oxygen Spectrum with Bright Lines in the Solar Spectrum	81
Dudley, W. L., Title of paper	248
Dynamo-electric Machines	160
Edison, Thos. A., A Resonant Tuning Fork	178
—— —— —— The Phenomena of heating Metals in vacuo by means of an Electric Current	173
Edison, Thos. A., Title of paper	210
Eisberg, Louis, The Explanation of Hereditary Transmission	520
Faradic Machines	178
Fellows	xlv
Gage, S. H., A New Method of demonstrating the Thoracic Duct in Animals	425
—— —— The Inter-articular Ligament of the Head of the Ribs in the Cat	421
Gases, Analysis	230
General Secretary, Report	541
Glacial Deposits in New England	299
Goode, G. Brown, Short Biography of the Menhaden	425
Hall, Asaph, Observations of Double Stars	65
Hamlin, A. C., Title of paper	248
Harkness, William, On the Color Correction of Achromatic Telescopes	96
Hedrick, Benjamin S., Title of paper	210
Hereditary Transmission	520
Hornaday, Wm. T., The Species of Bornean Orangs, with notes on their habits	438
Humus Acids, Geological Action	311
Hunt, T. Sterry, The History of some pre-Cambrian Rocks in America and Europe	279
Insect-habits	472
International Geological Congress, Report of Committee	43
Jade	523
Julien, Alexis A., The Geological Action of the Humus Acids	311
Langley, S. P., Address	51
Leeds, Albert R., Chemical Notes	236
Lepidopterous Insect, New species	467
Light, Velocity	124
Mallery, Garrick, The Sign Language of the North American Indians	493
Maple Sap	234
Marcellus Shale in Central Ohio	297
Marsden, Richard, Title of paper	210
Marsh, O. C., Address	1

Page

McMurtrie, Wm., The Limits of Meteorological Conditions, Governing the Extension of Beet-root Culture 242
Mechanical Energy 160
Meetings xvi
Meetings of Association Amer. Geologists and Naturalists xv
Members xxviii
Mendenhall, T. C., An Experimental Solution of a Problem in the Doctrine of Chances 190
Menhaden 425
Mercury, Observations on the Transit of 74
Meridian Instrument 77
——— Observers 106
Metals, heated in vacuo 173
Michelson, Albert A., Experimental Determination of the Velocity of Light 124
Minot, Charles Sedgwick, The Conditions to be filled by a Theory of Life 411
Morley, Edw. W., Results of Systematic Analyses of Air, to determine the Cause of the Variations in the Amount of Oxygen therein contained 229
Morley, Edw. W., Some Details in the Construction of an Apparatus for the Analysis of Gases 230
Muscæ volitantes 419

Nichols, Wm. Ripley, Titles of Papers 248
North American Indians, Sign Language 493

Officers, Boston Meeting xii
——— Saratoga Meeting vi
Order of Proceedings in Organizing Meeting xxvii
Osborne, J. W., Certain forms of Muscæ volitantes 419
——— — — Note on a Peculiar Case of Corrosion of the Metal Tin 232
Owen, Richard, Title of paper 210
Oxygen in Air 229
——— Spectrum 81

Patron xxviii
Peirce, Benjamin, Title of paper 209
Perkins, George H., Notes on the Archæology of the Champlain Valley 528
Permanent Secretary, Cash Account 566
——— ——— Report 563
Phillips, A. W., Title of paper 210
Powell, John W., Address 251
Pre-Cambrian Rocks 279
Putnam, F. W., Cash Account 566
——— ——— Report 563

Remsen, Ira, Address 213
Report of General Secretary 541
——— — Permanent Secretary 563
——— — the Committee on International Geological Congress 43
Retiring President, Address 1
Riley, C. V., Philosophy of the Pupation of Butterflies and particularly of the Nymphalidæ 455
Riley, C. V., The Cotton Worm in the United States 464
Richards, Ellen H., Title of paper 248
Rogers, Wm. A., The First Results from a New Diffraction Ruling Engine 184
——— ——— Titles of papers 209
Ruling Engine 184

	Page
Samuelson, James, Title of paper	210
Saratoga Meeting, Committee of Sections	vii
——— ——— Local Committee	viii
——— ——— Officers	vi
Scudder, Samuel H., Title of paper	210
Sign Language	493
Smith, Erminnie A., Monograph on Jade, illustrated with fine specimens of the different varieties. Abstract	523
Smith, Erminnie A., Title of paper	248
Solar Parallax	123
Solar Spectrum	81
Stone Implement from Vermont	526
Theory of Life, Conditions to be filled	411
Thoracic Duct, Method of demonstrating	425
Thurston, R. H., The Strength of American Timber	192
Tin, Corrosion	232
Titles of Communication	209, 248, 487, 540
Toad, crystals in Vertebra	415
Todd, D. P., Observations on the Transit of Mercury, 1876, May 6, including a Systematic Search for a Satellite, and Measures of the Diameter of the Planet	74
Trowbridge, John, Title of paper	209
Tuning Fork	178
Upham, Warren, The Succession of Glacial Deposits in New England	299
Upton, Francis R., Methods for Testing Faradic Machines	178
Van der Weyde, Title of paper	210
Velocity of Light	124
Vice President Langley, Address	51
Vice President Powell, Address	251
Warner, J. D., Title of paper	210
Wheeler, C. G., Title of paper	248
Whitfield, R. P., Notice of the Occurrence of Rocks Representing the Marcellus Shale of New York, in Central Ohio	297
Wiley, H. W., The Sugar content of the sap of the maple tree, and the pressure of the same	234
Wiley, H. W., Title of paper	248
Wright, A. W., Titles of papers	210
Young, C. A., Method of investigating the Errors produced by Irregularities in the form of the Pivots of a Meridian Instrument	77